6

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

BY

JOHN P.L. BACHARACH AND ASSOCIATES LIMITED
WITH
ASSOCIATED MINING CONSULTANTS LTD
NORWEST RESOURCE CONSULTANTS LTD
AND
WESTAR ENGINEERING LTD

PERMIT TO PRACTICE
John P. L. Bacharach and Associates Limited
Signature
Date Sept 21/84
PERMIT NUMBER: P 3874
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

MICROMEDIA
FEB 7 / 1985

DSS FILE NUMBER: 03SQ.23440-3-9187
DSS CONTRACT SERIAL NUMBER: OSQ83-00329
CANMET PROJECT NUMBER:
CANMET SCIENTIFIC AUTHORITY: DR. R.K. SINGHAL

178 pp

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD
DSS # 03SQ.23440-3-9187

PREPARED FOR

SUPPLY AND SERVICES CANADA

SUBMITTED BY

JOHN P.L. BACHARACH AND ASSOCIATES LIMITED
WITH
ASSOCIATED MINING CONSULTANTS LTD.
NORWEST RESOURCE CONSULTANTS LTD.
AND
WESTAR ENGINEERING LTD

SEPTEMBER 1984

AR-80

John P.L. Bacharach and Associates Limited

CONSULTING MINING ENGINEERS

October 5, 1984

REF: P14

Department of Energy, Mines and Resources
CANMET, Coal Research Laboratories
Bow Point Plaza
Room 380
4500, 16 Avenue N.W.
Calgary, Alberta
T3B 0M6

Attention: Dr. R.K. Singhal, P.Eng.
Scientific Authority

Dear Sirs:

Re: A Study of Alternative Longwall Facecutting Systems
DSS File # 03SQ.23440-3-9187
DSS Contract Serial No. 0SQ83-00329

We take pleasure in submitting our final report on Alternative Longwall Facecutting Systems.

We would like to thank the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada for sponsoring the study and for their advice and guidance during its execution.

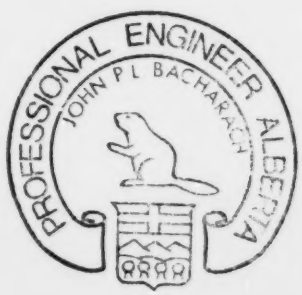
Yours truly,

JOHN P.L. BACHARACH AND ASSCCIATES LTD.

John Bacharach

John P.L. Bacharach, P.Eng.
President

JPLB/sds
enclosure



3818 - 1 Street SW, Calgary, Alberta, Canada, T2S 1R3 Tel: (403) 287-3343

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

Table of Contents

	Executive Summary
	Sommaire
SECTION 1	Introduction
SECTION 2	Frictional Ignition
SECTION 3	Ideal Mining System Parameters
SECTION 4	Cape Breton Mining Operations
SECTION 5	Review of Current and Emerging Concepts
SECTION 6	Possible Alternative Longwall Facecutting Systems
SECTION 7	Systems Applicable to Coalfield Conditions
SECTION 8	Conclusions and Recommendations
APPENDIX A	Selected Bibliography

EXECUTIVE SUMMARY

In an underground coal mining environment, frictional ignition may be defined as the ignition of an explosive air/methane/coal dust mixture by mining machinery. As the use of power loading equipment has become more widespread, frictional ignition incidents have increased. There have been many fatalities and injuries from this cause including the death of eleven miners in Cape Breton Development Corporation's No.26 Colliery in 1979.

Extensive research has been conducted into the nature of frictional ignition and the phenomenon is now well understood. Research on the means of minimizing the possibility of frictional ignition has centred around the design of cutting bits, water spray systems, improved ventilation and ignition extinguishing systems.

The most widely used mining machine is the double ended drum shearer and is used to secure a reduction of the frictional ignition hazard associated with drum shearers is receiving high priority in the Sydney Coalfield. The objective of this study is to identify a longwall facecutting system that is inherently safer than the shearer.

As the basis for identifying candidate systems for further consideration, the ideal parameters for a mining system are established. The most important of these are:

- adequate ventilation around the cutting elements at all times
- maintaining the cutting element in coal and out of contact with quartzitic rock
- replacing the mechanical cutting system with other, less incendive, cutting mechanisms.

The geology and mining operations in the Sydney Coalfield are reviewed and the greatest frictional ignition hazard identified as the roof and floor of the seams, particularly where sandstone channels are in close proximity to the mining horizon.

Currently longwall operations are being conducted in two mines, Lingan and Prince. Three other new mine projects are under development or consideration. All current or projected faces utilize shield supports, armoured face conveyors and related equipment. Lingan faces are advancing and those at Prince are retreating. All future faces in the new mines are planned to be retreated. A review of longwall performance indicates that a candidate system must be capable of achieving individual shift performances of 1500 tonnes and face productivities in a retreat mode in excess of 40 tonnes per manshift. Other technical characteristics required in an alternative system are defined and priority is accorded to those systems compatible with present mining equipment.

Past, current and emerging facecutting systems are reviewed to provide a background for the identification of candidate systems. The review indicates limiting parameters, operational difficulties and levels of productivity associated with various mining systems. The review highlights three options:

- slicer
- plough employing water jet cutting.
- hybrid shearer incorporating water jet cutting

Each of these systems has the potential to achieve satisfactory production and productivity levels whilst requiring minimum change to existing roof support and face conveying systems. To obtain the maximum benefit the systems identified should be employed in the retreat mining mode.

The current status of development of each of these three systems is discussed and modifications for improved performance are identified.

It is recommended that CANMET/CBDC carefully monitor the results of the current series of field trials with the water jet plough and that discussions be held with the proprietors of the slicer to review the possible updating of the slicing machine.

High priority should be given to the further evaluation and feasibility assessment of the hybrid shearer since this machine requires the least change to existing mining systems and appears to offer considerable potential for high productivity mining with minimum frictional ignition hazard.

SOMMAIRE

Dans un milieu minier, l'inflammation à friction peut être définie comme étant l'inflammation d'un mélange d'atmosphère inflammable et de poussières de méthane et de charbon, inflammation déclenchée par la machinerie minière. Comme le matériel d'abattage et chargement est de plus en plus puissant, les incidents d'inflammation à friction se sont accrus. Ce fut la cause de plusieurs blessures et accidents mortels y compris la mort de onze mineurs au Cape Breton Development Corporation's No.26 Colliery en 1979.

Une ample recherche a été faite sur la nature de l'inflammation à friction et ce phenomène est maintenant bien compris. La recherche sur les moyens de minimiser la possibilité d'inflammation à friction s'est concentrée sur le dessin des pics d'abattage, les systèmes d'arrosage, une meilleure ventilation et les systèmes d'extincteurs d'inflamation.

La machine la plus utilisée dans le champ de charbon de Sydney est la haveuse-chargeuse à tambour. Réduire les risques d'inflammation à friction associés à la haveuse-chargeuse à tambour est un but d'une haute priorité dans le champ de charbon de Sydney. L'objectif de cette présente étude est d'identifier un équipement de tailles mécanisé qui est intrinsiquement plus sûr que la haveuse-chargeuse à tambour.

Avant de pouvoir identifier certains équipements alternatifs, il est nécessaire de définir les câdres idéaux d'un système minier. Les plus importants de ces câdres sont:

- l'assurance d'une ventilation adéquate en tout temps dans les pics d'abattage
- le maintien des pics d'abattage dans le charbon et hors de contact avec la roche quartzitique
- remplacement de les pics d'abattage par un système moins susceptible a l'inflammation à friction.

Cette étude passe en revue la géologie et les opérations minières du champ de charbon de Sydney tout en signalant que les endroits où il y a le plus de danger d'inflammation à friction sont le toit et le plancher des veines, en particulier là où les canaux de grès sont à proximité de l'horizon minier.

Les opérations à tailles longues sont celles présentement en vigueur dans deux mines, Lingan et Prince. Trois autres nouveaux projects de mines sont sous considération ou déjà en développement. Toutes les tailles actuelles ou projetées emploient des piles-boucliers, des convoyeurs blindés et autres équipements semblables. Les tailles de la mine Lingan sont des tailles chassantes et celles de la mine Prince sont des tailles rabattantes. Il est prévu que toutes les tailles des nouvelles mines seront rabattantes. Une étude sur les performances des tailles longues indique qu'un équipement alternatif doit être capable d'avoir comme résultat des rendements par équipe individuelle de 1500 tonnes et de pouvoir produire selon un mode d'opération à tailles longues rabattantes plus de 40 tonnes par équipe individuelle. Cette présente étude précise d'autres caractéristiques techniques nécessaires à un système alternatif et présente plus spécialement ceux qui sont compatibles avec l'équipement minier actuel.

On passe ici en revue les équipements de tailles mécanisés passés, actuels ou en train d'être développés afin de fournir un arrière-plan aux systèmes proposés. Cette revue décrit les paramètres restreignants, les difficultés d'opération et les niveaux de productivité associée à une variété de systèmes miniers. Trois options ressortent de cette revue:

- "slicer"
- rabot utilisant des jets d'eau à haute pression
- haveuse-chargeuse à tambour "hybride" c.à.d. incorporant des jets d'eau à haute pression.

Chacun de ces systèmes a le potentiel d'accomplir une production et un rendement satisfaisants bien que ne nécessitant qu'un changement minimum aux supports des toits et aux convoyeurs présentement en place. Afin de

s'assurer un rendement maximum ces systèmes devraient être utilisés selon un mode d'opération à tailles longues rabattantes.

On discute dans cette étude l'état actuel de développement de ces trois systèmes et on indique certaines modifications qui en amélioreraient la performance. Le critère de performance de chacun de ces trois systèmes peut se comparer avantageusement à celui de la haveuse-chargeuse à tambour.

On recommande que CANMET/CBDC surveille soigneusement les résultats de la présente série d'essais sur place avec le rabot à jets d'eau à haute pression. On recommande aussi que des discussions aient lieu avec les propriétaires du "slicer" afin d'examiner la possibilité de moderniser cette machine.

On conseille plus spécialement une évaluation plus approfondie sur la praticabilité de la haveuse-chargeuse à tambour "hybride" puisque cette machine nécessiterait le moins de changements aux systèmes miniers actuels et elle semble offrir un potentiel considérable d'une haute productivité minière accompagnée d'un minimum de risques d'inflammation à friction.

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD DSS # 03SQ.23440-3-9187

SECTION 1 - INTRODUCTION

Table of Contents

		Page
1.1	Scope of Study	1-1
1.2	Approach	1-1

SECTION 1 - INTRODUCTION

1.1 SCOPE OF STUDY

The Statement of Work requested by CANMET/DSS defines the scope of the study as follows:

- Through literature review, correspondence, telephone conversations and personal visits, summarize geologic and other conditions in the Sydney coalfield that impact the choice of face cutting and loading equipment.
- Through literature review, correspondence, telephone conversations and personal visits, summarize emerging and developed concepts and equipment that could replace shearer-loaders on longwall faces in the Sydney coalfield.
- In describing the alternative face cutting and loading systems, the contractor is expected to discuss each system in sufficient detail to permit a technical assessment of the strengths, weaknesses and attainable level of performance of each system as well as propensity for frictional ignitions and compatibility with existing equipment.
- The various alternatives should be discussed with due regard to their state of development but emerging or unproven concepts, approaches, techniques and technologies must be included particularly when they offer significant advantages over existing technology.

1.2 APPROACH

The majority of the coal mined in the Cape Breton coalfield is produced by double ended ranging drum shearers (DERDS). These machines have proven their ability to mine at high production rates in the conditions prevailing in the Sydney Coalfield and experience with such machines extends over more than a decade.

Of significant concern in the use of DERDS is the high incidence of frictional ignitions which have contributed in the past to several fires and a major explosion. Considerable efforts have been made by CBDC and by other interested agencies to seek means of reducing the risk of frictional ignitions.

This study is directed towards identifying viable alternatives that offer a reduced frictional ignition hazard and complements the work already undertaken to reduce frictional ignition potential on DERDS installations.

In considering the feasibility of alternative cutting/loading techniques, the specific circumstances that exist in the Sydney Coalfield are reviewed from the perspective of geology, geotechnical data, mining environment, mining operations, performance and safety.

Potential alternative system are considered in the light of these factors, to determine their practicability of application. Our review of alternative cutting/loading technology is wide ranging both geographically and technologically and identifies systems that are well developed and those that are emerging or unproven. We have sought to achieve a balance between the identification of creative concepts and the practicability of effective implementation. In our view only those systems that have the potential of producing coal reliably at acceptable levels of productivity and safety are considered as candidates for further evaluation.

Alternative cutting/loading systems that replace the shearer loader, while retaining the rest of the existing longwall equipment and systems have been identified. These systems are believed to have the potential to reduce the frictional ignition hazard and to perform at satisfactory production and productivity levels.

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 2 - FRICTIONAL IGNITION

Table of Contents

		Page
2.1	**Introduction**	2-1
2.2	**Causes of Frictional Ignition**	2-3
2.3	**Minimizing Frictional Ignition Potential**	2-7
2.3.1	Bit Configuration	2-7
2.3.2	Bit Alignment	2-8
2.3.3	Bit Materials	2-9
2.3.4	Bit Cutting Speed	2-10
2.3.5	Application of Water Sprays	2-10
2.3.6	Ventilation	2-11
2.3.7	Ignition Quenching	2-12
2-4	**Remedial Measures**	2-13

TABLE
(Following Text)

2-1 Incidence of Frictional Ignitions, 1958-1981

FIGURES
(Following Table)

2-1 Relationship of Cutting Bit and Heated Surface

2-2 Ignition Temperatures for Plates of Varying Size and Position in an Explosion Box Containing 6% Methane

.....Cont'd

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD
DSS # 03SQ.23440-3-9187

SECTION 2 - FRICTIONAL IGNITION

Table of Contents Cont'd

FIGURES

2-3 Minimum Explosive Concentrations of Coal Dust in Methane/Air Atmospheres

2-4 Effect of Bit Wear on the Number of Strikes to Ignition

2-5 Definition of Bit Clearance Angle

2-6 Spray Nozzle Location for Ignition Suppression

SECTION 2 - FRICTIONAL IGNITION

2.1 INTRODUCTION

Frictional ignition may be defined as the ignition of gaseous and/or particulate matter by means of mechanical friction. In a mining setting, this is narrowed to mean the ignition of an explosive air-methane or air-methane-coal dust mixture by mining machinery.

Frictional ignition of methane in underground collieries has been recorded as early as the seventeenth century, but with the advent of modern mechanized mining systems it has become of particular concern. Table 2-1 shows the increasing incidence of frictional ignitions in both British and US coal mines during the past two decades (Powell, 1975; HM Inspectorate of Mines and Quarries, 1982; Courtney 1981).

During this same period of time, longwall systems came into increasing use and the proportion of frictional ignitions caused by shearer machines rose accordingly. (The greater number of incidents of frictional ignition in the United States coal mines compared to British coal mines can largely be attributed to the greater total underground production in the United States).

The increasing incidence of frictional ignition means also an increase in the likelihood of a major explosion capable of causing human casualties. An explosion at the Carbon Fuel No.2 Mine near Helper, Utah in 1963 killed 9 miners and an incident elsewhere in the US in 1970 left one man dead of asphyxiation. Both of these occurrences were attributed to a frictional ignition of methane by continuous coal cutting equipment (Stafford, 1981). In February 1979, frictional ignition was diagnosed as

the cause of a serious explosion in the Deveo No.26 Mine which claimed the lives of 11 miners. Three years later, in January of 1982, 40 miners were seriously injured in an explosion in Scotland's Cardowan Colliery which was also attributed to frictional ignition (HM Inspector of Mines and Quarries, 1982).

Though it is well known that the contact of coal cutting equipment with rock could produce a frictional ignition, the actual mechanism of ignition was not well understood; as a result of the increase in the number of frictional ignitions, research efforts have been undertaken to better understand its nature and minimize its occurrence. In this section of the report, the causes of frictional ignition, the current research efforts being made to minimize or eliminate its occurrence and a summary of remedial measures which may be implemented using current technologies is provided.

The investigation reports into frictional ignition reviewed to provide the necessary background for this study consist of two types of publication. The first contains the actual raw experimental data and conclusions of the original investigators. These investigations were usually conducted by governmental agencies and include work done by Britain's Safety in Mines Research Establishment and the US Bureau of Mines. The second consists of synoptic papers published on the subject of frictional ignition or related subjects that usually discuss and summarizes the work of several researchers. Review of these various publications leads to the following conclusions:

a. Research into the fundamental mechanisms of frictional ignition has been extensive and has led to essentially the same conclusions from all groups involved. This would imply that further research in this direction is probably not required.

b. Investigations centred around techniques to minimize or eliminate the incidence of frictional ignition produced sometimes contradictory conclusions and pointed to areas in which further research would be useful. The majority of original research reports reviewed for the preparation of this report were from the US Bureau of Mines (USBM), references were made to tests conducted by individuals or groups in Britain in the synoptic papers, but in a number of cases the original reports were not available for detailed review.

2.2 CAUSES OF FRICTIONAL IGNITION

Since the early 1970's a substantial amount of research has been undertaken in several countries with the objective of better understanding the nature of frictional ignition as it relates to the use of mechanized mining equipment. This research has largely been directed toward bench scale or full scale testing of cutting tools applied to stone surfaces in an atmosphere consisting of an explosive air-methane mixture or an air-methane-coal dust mixture. This approach to testing was based on the premise that frictional ignition occurs as the result of coal cutting equipment coming in contact with rock surfaces above, below, or within the coal seam while at the same time being in close proximity to a concentration of a methane-air mixture with proportions conducive to rapid combustion. Experimental results along with actual experience at working faces in mines confirm this premise.

In a gassy coal seam, essentially pure methane is liberated from the face into the working area while essentially pure air is being passed into the working area to mix with and dilute the methane and carry it away from the face. As this process occurs, it is inevitable that a flammable boundary layer (Courtney, 1981) forms at the face which is composed of an explosive mixture of air and methane (5% to 14% methane). If at

the same time a piece of mining machinery comes in contact with quartzitic or pyritic rock, a frictional ignition is likely to occur.

A review of 223 incidents of frictional ignition reported in the US over a six year period revealed that 64% of the incidents were caused by the cutting equipment striking the roof material, 22% were the result of contact with a seam inclusion, and 14% of the incidents occurred as a result of cutting equipment coming in contact with the floor material (Golledge, 1981). The greater proportion of incidents near the roof is expected since the density of an air-methane mixture is less than that of the surrounding uncontaminated air.

Much of the laboratory research has been directed toward determining the actual mechanism of ignition at the rock/cutting tool contact. By using techniques such as high-speed photography and optical pyrometry, it has been conclusively determined that the initial ignition of an air-methane mixture occurs some distance (10 cm - 30 cm) behind the cutting tool along a 'hot streak' of molten metal and rock, created by the conversion of mechanical energy into thermal energy by sliding friction (Powell, 1975). Figure 2-1 shows the relationship of the heated surface caused by sliding friction to the bit orientation and cutting direction. This is contrary to the notion that it is the obvious sparks which are the instigators of ignition. Several tests were conducted in which profuse showers of sparks were generated by the cutting tool in a highly explosive atmosphere, but ignition did not occur (Blickensderfer, 1974). Pyrometric measurements indicate that the temperature of the heated surface behind the cutting tool can be as high as 1400°C (Laurendeau, 1982), which is more than adequate to ignite an explosive air-methane mixture.

There is an important relationship between the size (lateral area) of the heated surface and the ignition temperature of an air-methane mixture. Results of experiments show that the minimum temperature required to

ignite an explosive air-methane mixture decreases as the area of the heated surface increases (Laurendeau, 1982). Figure 2-2 shows the relationship between heated surface area and minimum ignition temperature. The implications of this effect are evident when bit wear and cutting speed are considered.

The interaction of coal dust in frictional ignition has also been studied to determine its role, if any, in the ignition process. Results of this research show that by itself, coal dust cannot be ignited by mechanical friction, as the minimum ignition energy of coal dust is 10 to 100 times that of an air-methane mixture (Courtney, 1981). However, it has been shown that when coal dust is present in conjunction with an explosive air-methane mixture, ignition of the methane mixture will, in turn, ignite the coal dust which increases the overall intensity of the explosion. Furthermore, experimental evidence indicates that when methane and coal dust are present in air, the lower limit of explosibility of each is lowered depending on their relative concentration in the mixture (Golledge, 1981). Figure 2-3 shows the interaction of air-methane-coal dust mixtures relative to the minimum explosive concentrations of the constituents of the mixture.

The likelihood of a cutting tool contact causing a heated surface temperature capable of igniting a gaseous mixture is very much dependent on the type of rock which is being struck by the cutting tool. Virtually all researchers agree, along with those with practical operating experience, that the incendive potential of a rock/cutting tool contact is proportional to the quartz content of the rock. The size of the quartz grains is also a factor in the incendive potential of a particular rock type. An average grain size greater than 70 microns is usually necessary to promote frictional ignition (Powell, 1975). For this reason, quartzitic sandstones are particularly conducive to the occurrence of frictional ignition. Pyrite intrusions which are occasionally encountered in coal seams have also been shown to have a significant

frictional ignition potential, though the mechanism of ignition is somewhat different than that of a steel/quartz contact. In the case of pyrite, the sparks produced by the contact are pieces of burning pyrite dust which are being oxidized by the air and which burn hot enough to initiate ignition of a gaseous mixture. Britain's National Coal Board (NCB) has ranked various rock types and compositions on the basis of their potential for frictional ignition of an air-methane mixture (NCB, PI/1974/4).

"Incendive Rocks

"1. The only two minerals likely to be encountered in British coal mines which can produce an incendive temperature when struck by machine picks, are **quartz** and **pyrites.**

"2. Quartz is present in most coal measures sediments and varies in both amount and grain size. In general, the higher the quartz content and the stronger the rock the greater will be the risk of producing an incendive temperature. Experience and research work to date has indicted that the Incendive Temperature Potential (ITP) of rocks can be related to the proportion of the quartz grains over 5μ in diameter as follows:-

Rocks containing over 50% quarts - High I.T.P.
" " 30% to 50% " - Intermediate I.T.P.
" " under 30% " - Negligible I.T.P.

"3. Sandstones usually contain 50% to 75% quartz with the grains 20 to over 200μ, usually well cemented giving a strong rock. Exceptionally, quartz contents can be over 90% as in the case of ganister and orthoquartzites. Infrequently, precipitated quartz occurs in lenses or irregular bands in coal seams and is known as 'quartzlagen'. Quartz contents of 80% have been recorded in such bands.

"4. Siltstones usually have quartz contents of 20% to 50% and mudstones less than 20%. The coarser siltstones or finely interbanded siltstones/sandstones generally have quartz contents of 30% - 50% and have an intermediate I.T.P.

"5. **Pyrites** is commonly found in and adjacent to coal seams. Massive pyrites, strong highly pyritic dirt bands, and ironstone with pyrites, probably have an intermediate I.T.P.* and pyritic sandstones or siltstones or siltstone-seatearths a high I.T.P. Experience has indicated that the combination of a high quartz content rock and pyritic rock (e.g. pyritic sandstone) represents the most incendive type of strata likely to be encountered in coal mines.

"* Work to date has not established the relative potentials of the different types of pyrite occurrence."

2.3 MINIMIZING FRICTIONAL IGNITION POTENTIAL

Research into measures to minimize the possibility of frictional ignition has centred around the design of cutting bits, water spray systems for cutting bits, improved ventilation practices and initial ignition extinguishing systems. Most of the research was carried out with laboratory scale equipment designed to simulate the performance of mining equipment, but some of the more important results were obtained by the use of actual coal cutting machinery. Because of the probabilistic nature of frictional ignition and the numerous variables involved, the results of this research are somewhat qualitative in nature and therefore are meant to indicate trends and tendencies rather than provide absolute values.

2.3.1 Bit Configuration

Most modern coal cutting equipment uses one of two basic bit designs: conical or 'plumb bob' type bits and radial or 'flat' bits. Continuous miners are usually equipped with ripper heads fitted with conical bits, but in North America the vast majority of drum shearers on longwall faces use flat bits. In the UK there is about a 50-50 split between the two (Hislop, 1984). On the basis of bit design only, there is some evidence that one of the two designs

shows an increased tendency toward frictional ignition. In tests conducted by the USBM it was found that a radial bit showed a tendency to produce fewer frictional ignitions than a conical bit operating under the same conditions (Roepke, 1982). In another series of USBM experiments, the researchers asserted the premise that in the case of conical bits, a smaller bit diameter decreased the incendive potential of the bit and concluded that future designs for conical bits should incorporate this finding (Larson, 1983). More importantly, virtually all researchers agree, with the peculiar exception of one research group in the Soviet Union (Kocherga, 1981) that the probability of frictional ignition is directly proportional to the amount of bit wear. Namely that a badly worn or poorly maintained bit has a much greater potential for initiating a frictional ignition than a sharp, well maintained bit. This is due to the fact that a worn bit will contact the cutting surface with a greater surface area and will, therefore, leave a larger zone of heated material behind the bit. Figure 2-4 shows the results of a USBM test using a radial bit mounted on a flywheel to cut into a sandstone block while enclosed in an atmosphere composed of an explosive air-methane mixture (Bituminous Coal Research, 1982). The figure shows the relationship between the amount of bit wear and the number of times the bit struck the sandstone block before an ignition occurred.

2.3.2 Bit Alignment

The attitude of the cutting surface of the bit with respect to the mining face is critical when considering ignition potential. Research using actual cutting bits from coal cutting machines has shown that in order to minimize the possibility of a frictional ignition, a bit must be oriented such that the tip of the bit strikes the cutting surface with a 'positive' clearance angle (Roepke, 1982). Figure 2-5 defines what is meant by a positive clearance

angle. A negative clearance angle may occur as a result of improper positioning of the bit on the cutter drum, or more commonly, as the result of bit wear. Conical bits are particularly suceptible to the formation of a negative clearance angle through bit wear. If the bit, which is usually free to rotate in its holder, becomes jammed in the holder, it will wear unevenly and become flat on the cutting side and develop a negative clearance angle. Furthermore, it has been shown that though a cutting bit may still have its carbide insert intact, a flat area on the insert is capable of producing a frictional ignition. Therefore, to minimize the possibility of a frictional ignition, the bit must always be maintained in a manner that will prevent the existence or formation of a negative clearance angle.

2.3.3 Bit Materials

The composition of bit components have been investigated to determine the effect of bit materials on incendive potential. Results of early research in the UK concluded that the bit material had a negligible effect on ignition potential (Powell, 1975). However, more recent studies conducted by the US Bureau of Mines suggests that the type of material constituting the cutting bit has a significant effect on the potential for producing a frictional ignition (Blickensderfer, 1974). In this study, numerous steels and alloys were tested and compared for incendive potential. It was found that the type of steel most commonly used in coal cutting bits had the highest incendive potential. Stainless steel and a nickel alloy steel were found to have a somewhat lower ignition potential. The lowest ignition potential was achieved by the use of a hard metal alloy composed of titanium, boron, copper and nickel. The USBM study suggested that this hard metal alloy be used to replace conventional

tungsten carbide tips in bits and that a hardenable stainless steel be used for bit shanks.

2.3.4 Bit Cutting Speed

A considerable amount of attention has been given to the question of cutting speed as it relates to frictional ignition potential. Reducing the cutting speed reduces the size and temperature of the heated surface behind the bit and hence the possibility of frictional ignition (Blickensderfer, 1974). Unfortunately, there is not a general agreement on the threshold speed below which frictional ignition is unlikely to occur. Critical tangential cutting speeds ranging from 0.5 m/sec to 1.78 m/sec have been reported, though speeds in this range are impractical from a production standpoint. Most cutter drums operate in the range between 3 m/sec to 6 m/sec. In response to an increase in the number of incidents of frictional ignition in British coal mines, the cutting speed was reduced from 5 m/sec to 3 m/sec (Lewis, 1983). Unfortunately, there has been no apparent reduction in the frequency of ignition incidents as a result of this action. In a related matter, consideration of the traverse speed of a cutter drum across the face has led to the conclusion that traverse speed has no noticeable influence on frictional ignition potential (Lewis, 1983).

2.3.5 Application of Water Sprays

Detailed studies by several groups have been carried out to determine whether the application of water sprays to the rock-cutting bit contact had an effect on reducing the frictional ignition potential. Virtually all modern coal cutting machines are equipped with dust suppression systems which consist of water sprays directed from the cutter head toward the face. However,

frictional ignitions still occur regardless of the water flow from dust suppression systems. This led researchers to concentrate on evaluating water sprays directed at individual cutter bits. Several spray configurations were considered, including: sprays directed in front of the bit (both jet and cone sprays), sprays carried through the pick, and sprays directed behind the pick (both jet and cone sprays). Water sprays directed to strike the cutting surface in front of the bit had a negligible effect on reducing frictional ignition, regardless of whether the spray was discharged as a jet or as a cone. Water carried through the pick had a marginal effect on reducing incidents of frictional ignition, but the orifice was easily clogged by rock fragments and steel from the bit as the bit wore down. A cone spray directed to strike the cutting surface behind the bit was found to be virtually 100% effective in eliminating the incidence of frictional ignition (Bituminous Coal Research, 1982). This finding is consistent with the notion that the initial ignition occurs along the heated surface behind the bit. It was also determined that a jet spray directed behind the bit was less consistent in preventing ignition than a cone spray. A diagram depicting the optimal nozzle location and spray pattern for ignition suppression is shown in Figure 2-6. A minimum water flow of about 2 L per minute per bit was necessary to achieve 100% ignition prevention (Watson, 1981).

2.3.6 Ventilation

Although mines generally provide the air quantities necessary to comply with health and safety regulations, it is difficult to deliver the required quantities of air to all parts of the working face. Investigations into the patterns of air flow around cutting machines show that regions of low velocity air often exist around the machine that can allow the accumulation of explosive concentrations of methane (Bingham, 1981). These concentrations of

air-methane may be considered as localized pockets or clouds. Statistical studies conducted by the Mine Safety and Health Administration on frictional ignitions in US coal mines show that the severity of methane explosions initiated by frictional ignition and the resulting injuries are a function of the distance between the coal face and the ventilation controls such as auxiliary fans, line curtains, etc. (Kawenski, 1979). In an attempt to increase air flow in the direct vicinity of a shearer loader, some designs incorporate a hollow shaft for the drum through which an air-water mixture is passed toward the face. In a hollow shaft ventilation system (HSV) the air is moved to the face by a high velocity water jet passing through the shaft. This requires relatively high water pressure which is sometimes difficult to obtain from a regular mine water supply. To provide the necessary pressure, auxiliary pumps have been employed in the working area and water at the appropriate pressure supplied to the shearer by a travelling hose feed. Having a high pressure hose moving along the face with the shearer can pose some operating problems, and trials have been conducted in which a high pressure pump has been incorporated into the shearer machine (Bingham, 1981). Hollow shaft ventilation can improve ventilation at the face but by itself it may not be enough to provide the necessary protection against the accumulation of explosive pockets of methane. At the time of the explosion at Cardowan Colliery, an HSV system was in operation at the face where the explosion initiated. The strategic placement of secondary air movers at the face may also be required to achieve the desired level of methane dilution.

2.3.7 Ignition Quenching

Research has been conducted to develop systems which may be used to quench incipient frictional ignitions. After initial

ignition, there is a period of several miliseconds during which the size of the flame is only a few centimetres in diameter. By using an ultraviolet flame detector, quenching systems which send a stream of extinctive material by means of a flameless explosive charge to the point where the ignition initiated have been developed (Watson, 1981). Though still in the experimental stages of development, quenching systems may become an important part of future efforts to eliminate the initiation of large scale methane explosions.

2.4 REMEDIAL MEASURES

Based on the findings of research undertaken, there are a number of measures which should be taken at mines which employ conventional coal cutting equipment such as continuous miners or shearer loaders using current available technologies. They include:

- Careful monitoring of current and anticipated geologic conditions using data gathered during exploration and development work. By identifying areas with frictional ignition potential equipment operators must be made aware when caution should be taken during mining operations. This will require the establishment of a good communication system between operators, mine geologists and engineers.

- Reducing cutter speed. This action might reduce the frictional ignition potential, but may provide more psychological benefit than anything else.

- Good maintenance of cutting equipment, specifically the cutter bits. Regular inspection of bits and replacement when necessary will have a significant effect on reducing the potential for frictional ignition. If the cutting equipment is currently using conical bits, it may be beneficial to change to a system which has the capability of using radial bits.

- Making provisions to maintain adequate ventilation at critical areas in the immediate vicinity of the face. This includes detailed monitoring of methane levels in the critical areas (i.e. near the roof, around the cutting machine, etc.). The use of

auxiliary fans at working faces and shearers with HSV capability are important in cases where accumulation of methane pockets is a frequent occurrence.

- Implementation of cutting systems which have sprays directed behind each bit. Many manufacturers have equipment available with this capability.

TABLE 2-1
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

INCIDENCE OF FRICTIONAL IGNITIONS, 1958 - 1981
(Continuous Coal Cutting Equipment)

YEAR	UK	US
1958	8	NA
1959	5	NA
1960	14	NA
1961	8	NA
1962	8	NA
1963	8	NA
1964	10	NA
1965	9	NA
1966	23	NA
1967	14	NA
1968	21	NA
1969	19	NA
1970	17	NA
1971	14	30
1972	5	20
1973	17	22
1974	17	44
1975	12	50
1976	13	61
1977	24	44
1978	11	38
1979	12	87
1980	14	NA
1981	24	NA

NA = Data not available. Prior to 1971, reporting of frictional ignition incidents was not mandatory in the US, thus data pertaining to events before 1971 may be inaccurate or inconsistent in reporting methods.

FIGURE 2-1

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

RELATIONSHIP OF CUTTING BIT AND HEATED SURFACE

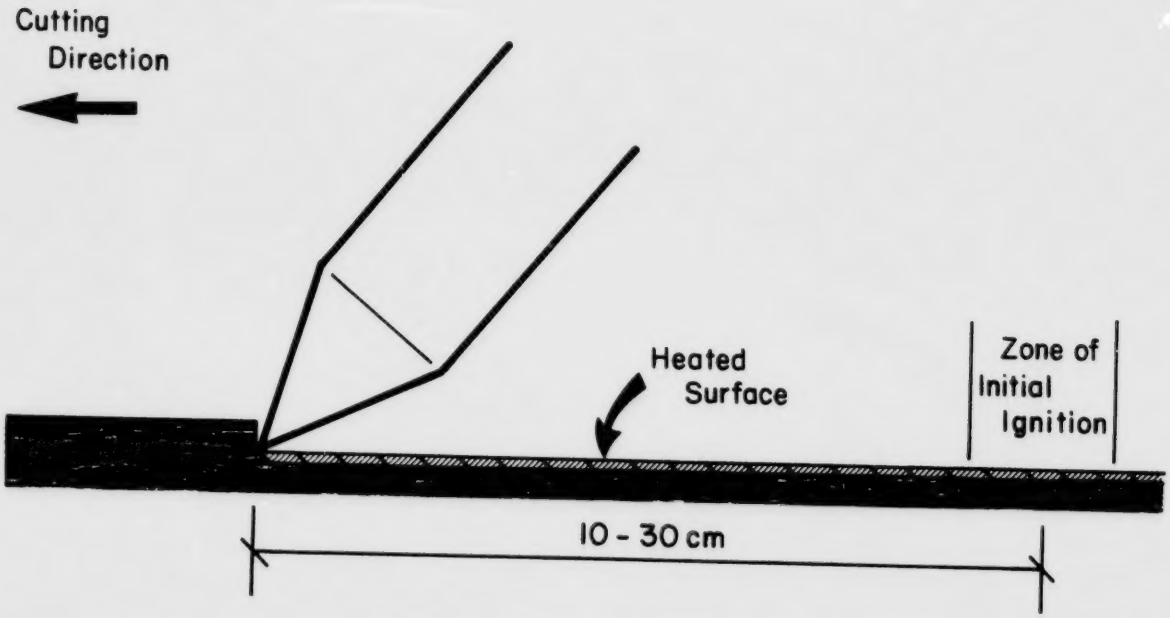


FIGURE 2-2
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

IGNITION TEMPERATURES FOR PLATES OF VARYING SIZE AND POSITION IN AN EXPLOSION BOX CONTAINING 6% METHANE

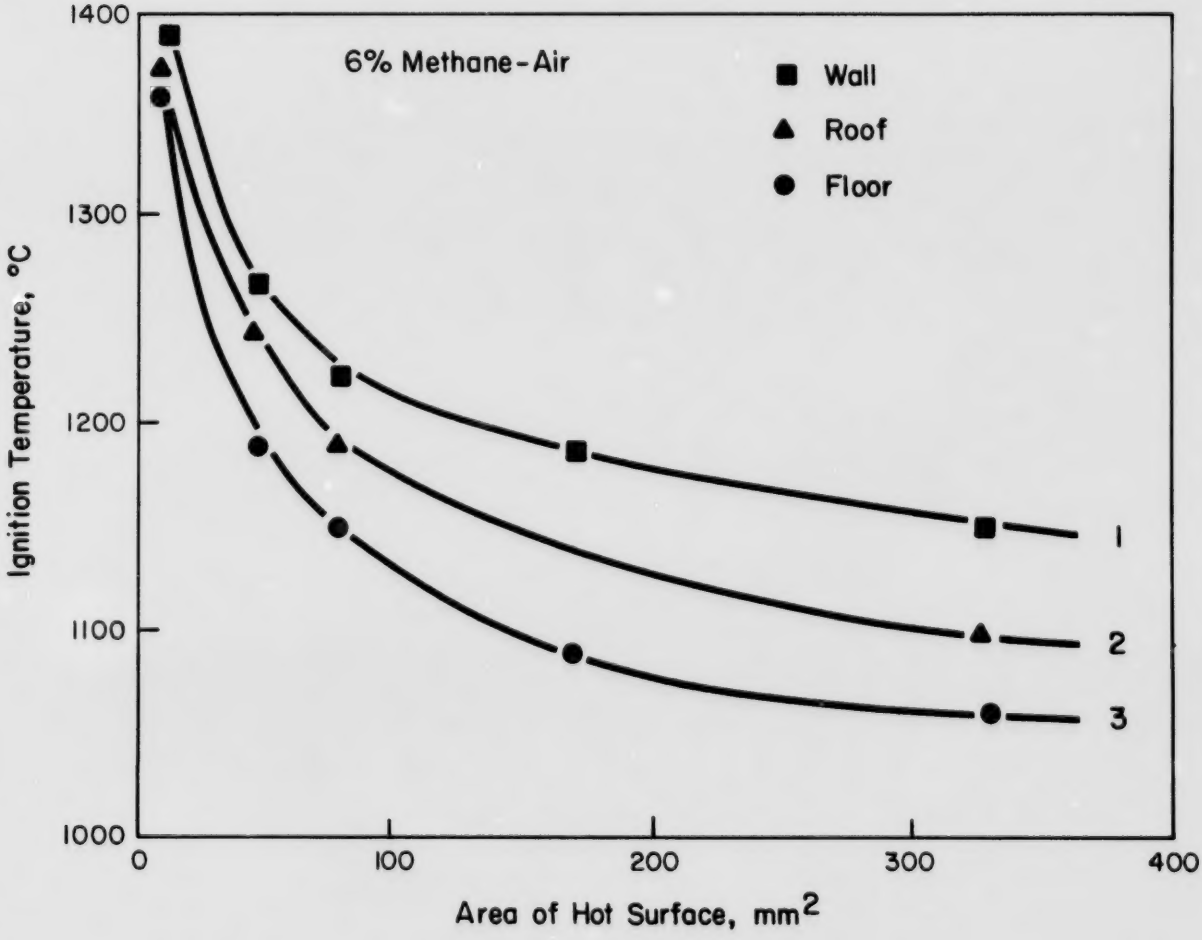


FIGURE 2-3
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

MINIMUM EXPLOSIVE CONCENTRATIONS OF COAL DUST IN METHANE/AIR ATMOSPHERES

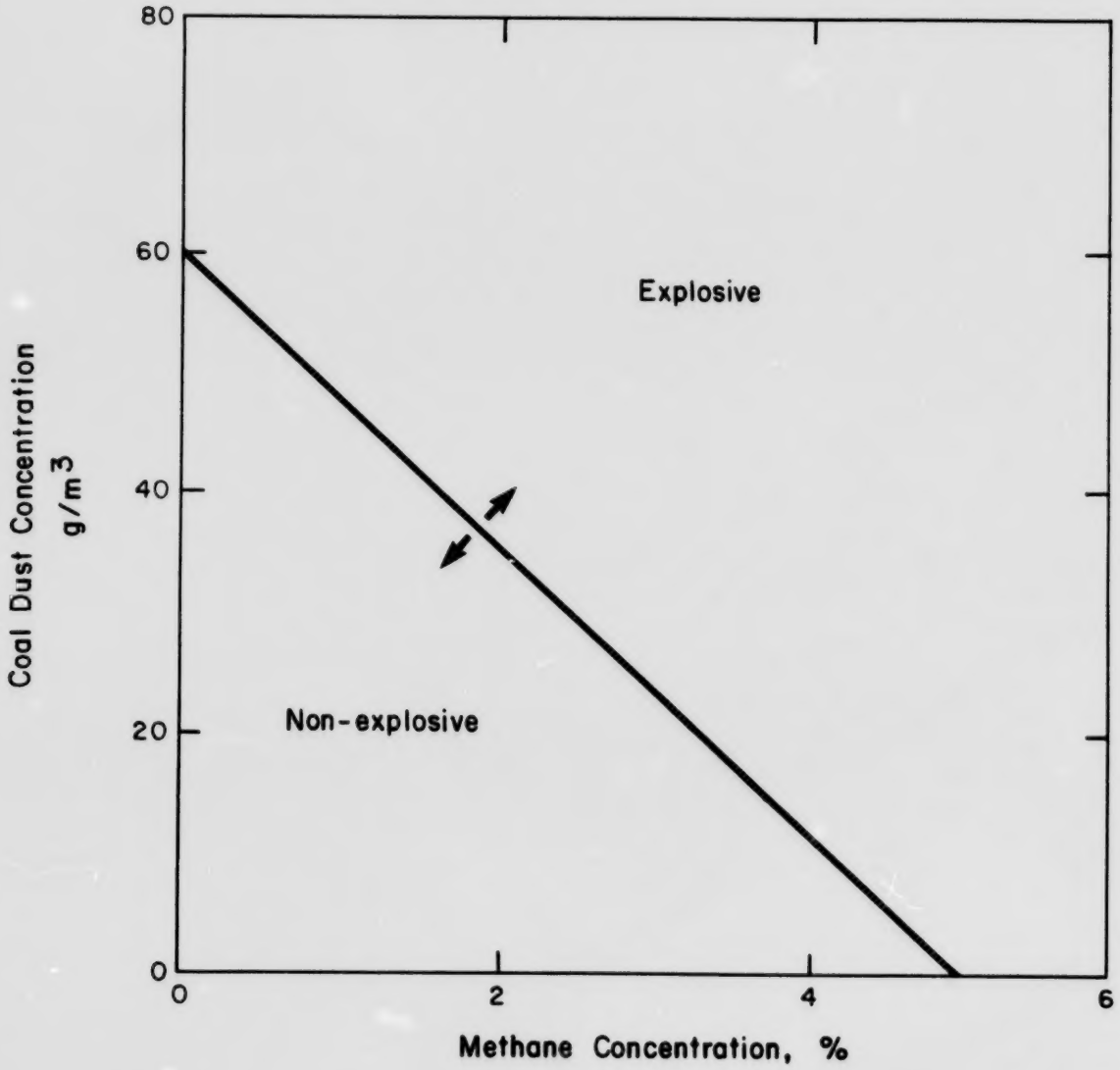


FIGURE 2-4

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

EFFECT OF BIT WEAR ON THE NUMBER OF STRIKES TO IGNITION

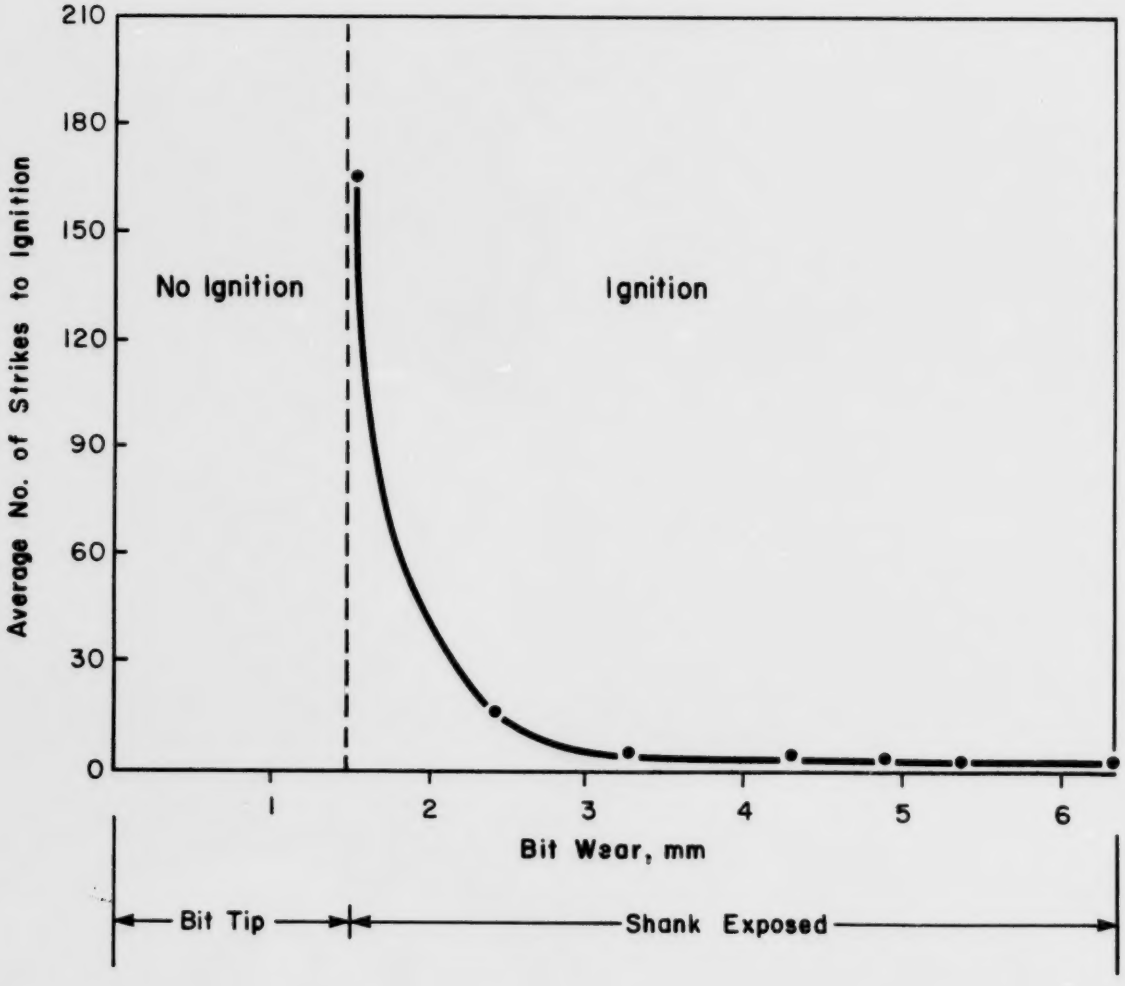
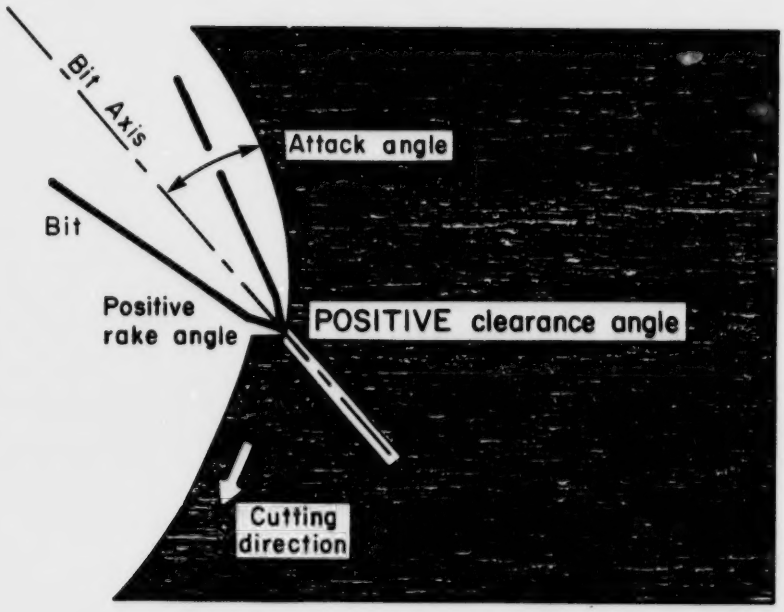


FIGURE 2-5

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

DEFINITION OF BIT CLEARANCE ANGLE



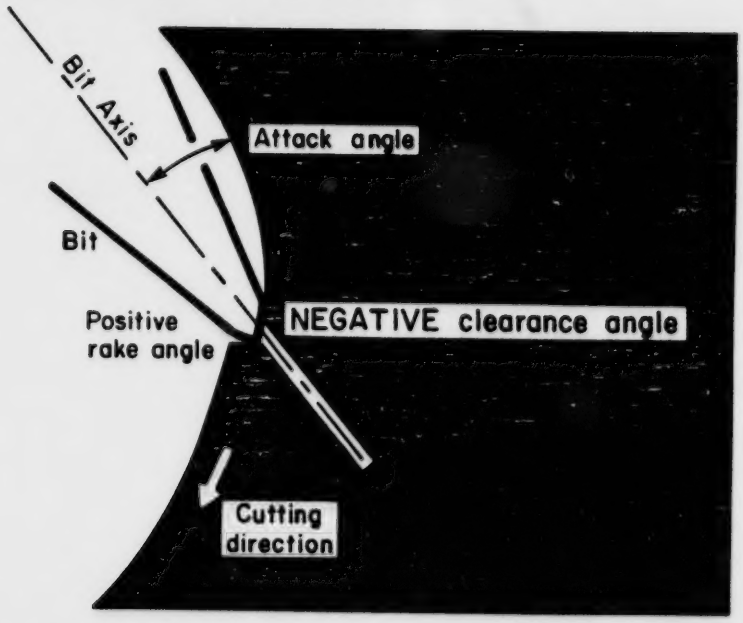
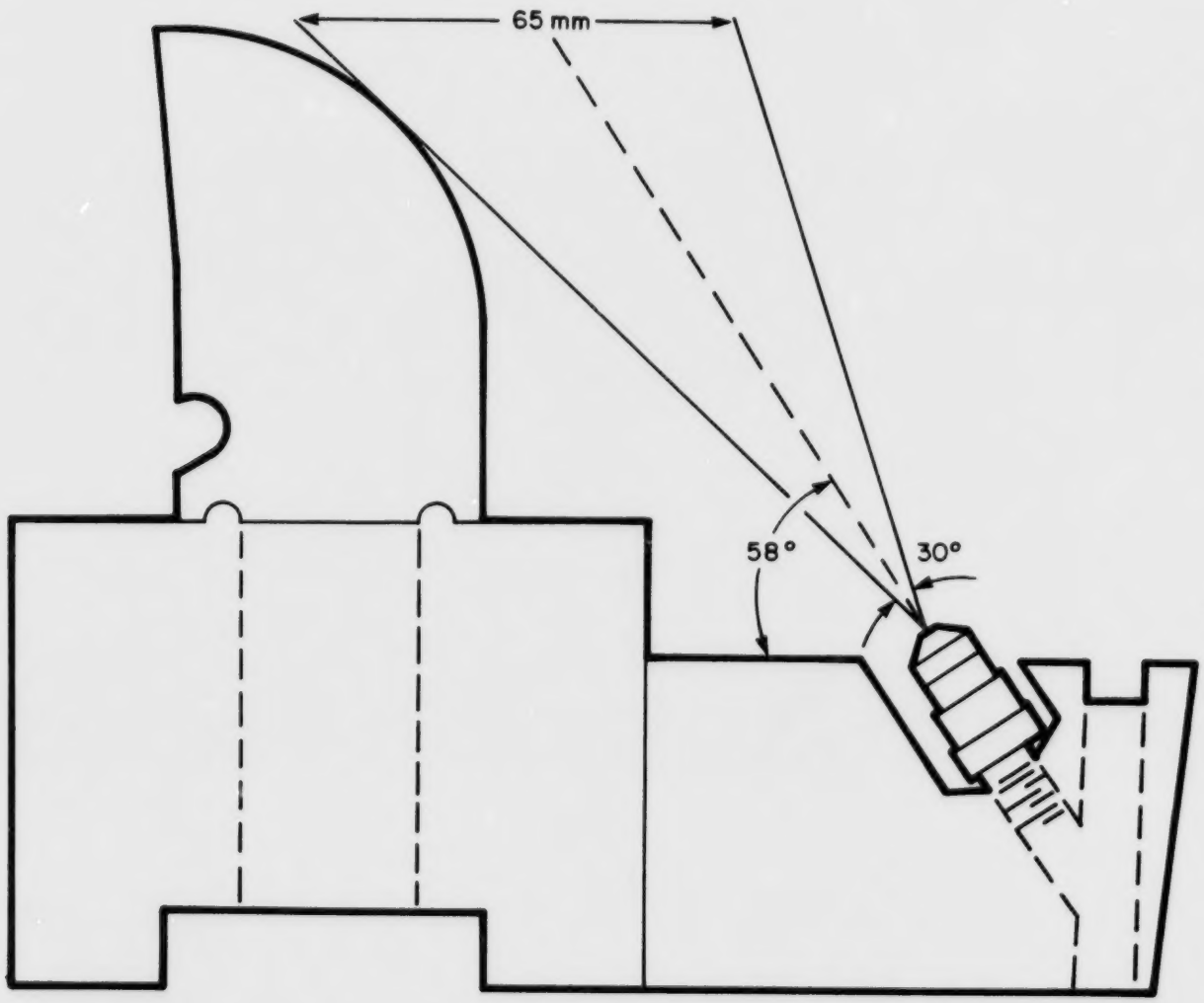


FIGURE 2-6

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SPRAY NOZZLE LOCATIONS FOR IGNITION SUPPRESSION



ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD DSS # 03SQ.23440-3-9187

SECTION 3 - IDEAL MINING SYSTEM PARAMETERS

Table of Contents

		Page
3.1	**Introduction**	3-1
3.2	**Mining Environment**	3-1
3.3	**Mining Process**	3-3
3.3.1	Ventilation	3-3
3.3.2	Cutting Bit Speed	3-4
3.3.3	Cutting Bits	3-4
3.3.4	Sprays and Spray Location	3-5
3.3.5	Mining Layout	3-5
3.4	**Summary**	3-6

FIGURES
(Following Text)

3-1 Critical Elements for Frictional Ignition

3-2 Idealized Mining System Parameters for Minimizing Frictional Ignition Potential

SECTION 3 - IDEAL MINING SYSTEM PARAMETERS

3.1 INTRODUCTION

To minimize or eliminate frictional ignition problems in longwall mining faces, the mining system parameters to be considered can be classified as mining environment-related and equipment/system-related. The former includes reserve characteristics such as geologic and geotechnical conditions and the latter includes mining equipment and mining methodologies. Both are of equal concern in addressing the potential for frictional ignitions since the two are closely interrelated.

In this section the information presented in Section 2 has been used to define the mining system parameters which will minimize and/or eliminate frictional ignition problems.

3.2 MINING ENVIRONMENT

The mining environment is, to a large degree, a function of the geologic and geotechnical characteristics of a coal reserve. The critical element of these characteristics is the presence or absence of methane since a methane-air mixture is required for ignitions to occur. Other factors of concern include the lithologies which are found in association with the coal to be mined and their potential for being intersected by mining equipment which can generate sufficient heat via friction to ignite the methane-air mixture.

The methane generation potential of a given coal deposit can be determined by conducting gas generation tests on cores from exploration drillholes and by monitoring gas concentrations in existing coal mine faces. Most researchers generally conclude that frictional

ignitions occur in a methane-air mixture which ranges from 5% to 15% methane with the optimum ignition level in the 6% to 8% range.

Methane-air mixtures are less dense than the air and usually occur or migrate to and concentrate at the roof and on the up-dip sides of mine openings. However, methane can be encountered at or below floor level in the seams and this also may present a significant hazard. Methane-air-coal dust mixtures are also likely to occur in similar positions and have been found to be explosive at relatively low methane concentrations when the proportion of coal dust is high (Figure 3-3). The presence of coal dust in a methane-air mixture has a tendency to allow the widespread propagation and intensification of an explosion in conjunction with a frictional ignition.

Frictional ignitions caused by the cutting of lithologies found in association with coal seams, are related to the quartz and/or pyrite content of these lithologies. Studies indicate that the coarser-grained, quartz-rich strata (usually sandstones) and/or pyrite inclusions commonly cause frictional ignitions when heated by cutting pick contact during mining. Finer-grained materials such as mudstones, siltstones, ironstones and limestones are rated as having a much lower potential for frictional ignitions.

Such incendive promoting lithologies are encountered in underground coal mines in the form of sandstone roof and floor strata, clastic dikes (spars), igneous intrusions and faults disseminated throughout the coal. Such lithologies are sometimes avoidable in mines where sufficient coal is available to leave top and bottom coal in place and where mine geology is sufficiently well understood to allow the accurate prediction of lithologies with a high incendive potential. However, coal thicknesses are rarely sufficient to avoid all potential ignition producing materials and frequently these materials must be contended with on a regular basis.

An ideal situation is either the absence of coarse-grained, quartz-rich material and pyrite, or sufficient coal thickness to permit avoidance of the strata which encloses the mineable coal seam and the absence of methane emissions. In practice, at many mines, such circumstances do not prevail.

3.3 MINING PROCESS

The mining process may allow critical methane-air mixtures to develop and provide the mechanical interaction with the mining environment wherein frictional heat-generating incidents can develop. The features which may contribute toward this potential for a frictional ignition incident are described below.

3.3.1 Ventilation

An important aspect of frictional ignitions is the size of the methane-air pocket which has the requisite characteristics to ignite. Although the methane and coal dust content of the pocket is important, the size of the pocket determines the severity and intensity of the explosion which results from frictional ignition. In addition to ventilation devices which may be employed along the coal face, due consideration must be paid to the total mine ventilation system.

Interruptions to ventilation disrupts uniform dispersal of methane concentrations and can result in 'slugs' of methane concentrations of critical proportions passing along the longwall face. Such 'slugs' can become the source of an explosion if they pass mining machine while frictional heating is occurring.

The dispersal of methane generated along a longwall face is not uniform, with eddys of concentrated methane occurring on the

'downwind' side of the mining machine. The dispersal of methane can be assisted by the use of the hollow shaft ventilator system.

Ventilation of the bulk of the cut is critical and machines taking a narrow web present less difficulties in this regard.

The density of the methane-air pocket is such that it rises to a higher level relative to the mine air and can become trapped on the up-dip sides of openings, above abandoned workings and at the roof of active mining faces. Particular care should be taken to avoid frictional ignition-causing activities in such areas and to ensure that such pockets are dispersed and mixed with the mine air at concentrations well below the lower explosive limit.

3.3.2 Cutting Bit Speed

Research on bit cutting speeds indicates that cutting speeds of approximately half of that currently employed for efficient coal extraction are required to significantly reduce the frictional ignition potential.

In the conventional use of rotating shearer drums, such an approach is probably unreasonable due to productivity requirements, even if slower cutting speeds are only used when the shearer drum approaches the roof or floor.

3.3.3 Cutting Bits

Studies indicate that sharp, properly maintained bits with 'positive' clearance are least likely to promote frictional ignitions, the primary cause of frictional ignitions being related to bit wear. Some researchers find that radial bits, the bit type most commonly used on North American longwall faces, have a

somewhat lower potential for causing frictional ignitions than conical bits, although smaller conical bit diameters exhibit similar results.

3.3.4 Sprays and Spray Locations

Researchers indicate that 'back-spraying' with sprays directed immediately behind the cutting bit is one effective means of reducing the incidence of frictional ignitions.

3.3.5 Mining Layout

The mining layout employed, i.e., either retreat or advancing, can have a significant effect on the ability to maintain an early awareness of frictional ignition hazards and to apply the best techniques for control and maintenance of the ventilation system.

The retreat mining system appears to offer advantage in this respect such as:

- a better knowledge of the geologic conditions can be obtained from the roadway drivages developed prior to installation of the longwall face
- ventilation leakage through the goaf areas is minimized
- development into 'blind ends' necessary with advance systems are not required and ventilation and control problems are eased
- mining machines cut out into already developed roadways and hazardous locations where incendive sparking may occur can be readily identified prior to mining these areas.

The most appropriate mining layout to be employed to assist in mitigating the potential for frictional ignitions is the retreat mining system.

3.4 SUMMARY

The development of frictional ignitions is a function of the mining environment and the mining process/system (Figure 3-1).

An ideal mining process would:

- ensure adequate ventilation around the cutting elements at all times
- maintain the cutting element in coal and out of quartzitic rock
- employ only sharp cutting picks operating at reduced cutting speed
- be equipped with sprays installed to quench any area of frictional heating that may occur.

To approach an ideal design for a longwall mining system a thorough knowledge of the mining environment is necessary in order to predict the location and likelihood of frictional ignition potential. A well developed communication system to disseminate this knowledge, is required and a mining process which is specifically designed to minimize the development of frictional ignitions coupled with good maintenance and operating procedures is necessary. The ventilation aspects of dispersing a critical methane-air pocket are particularly important. The interaction of these idealized elements of an optimized mining system is presented in Figure 3-2. The implementation of such a program will minimize but not eliminate the potential for frictional ignitions.

FIGURE 3-1
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

CRITICAL ELEMENTS FOR FRICTIONAL IGNITION

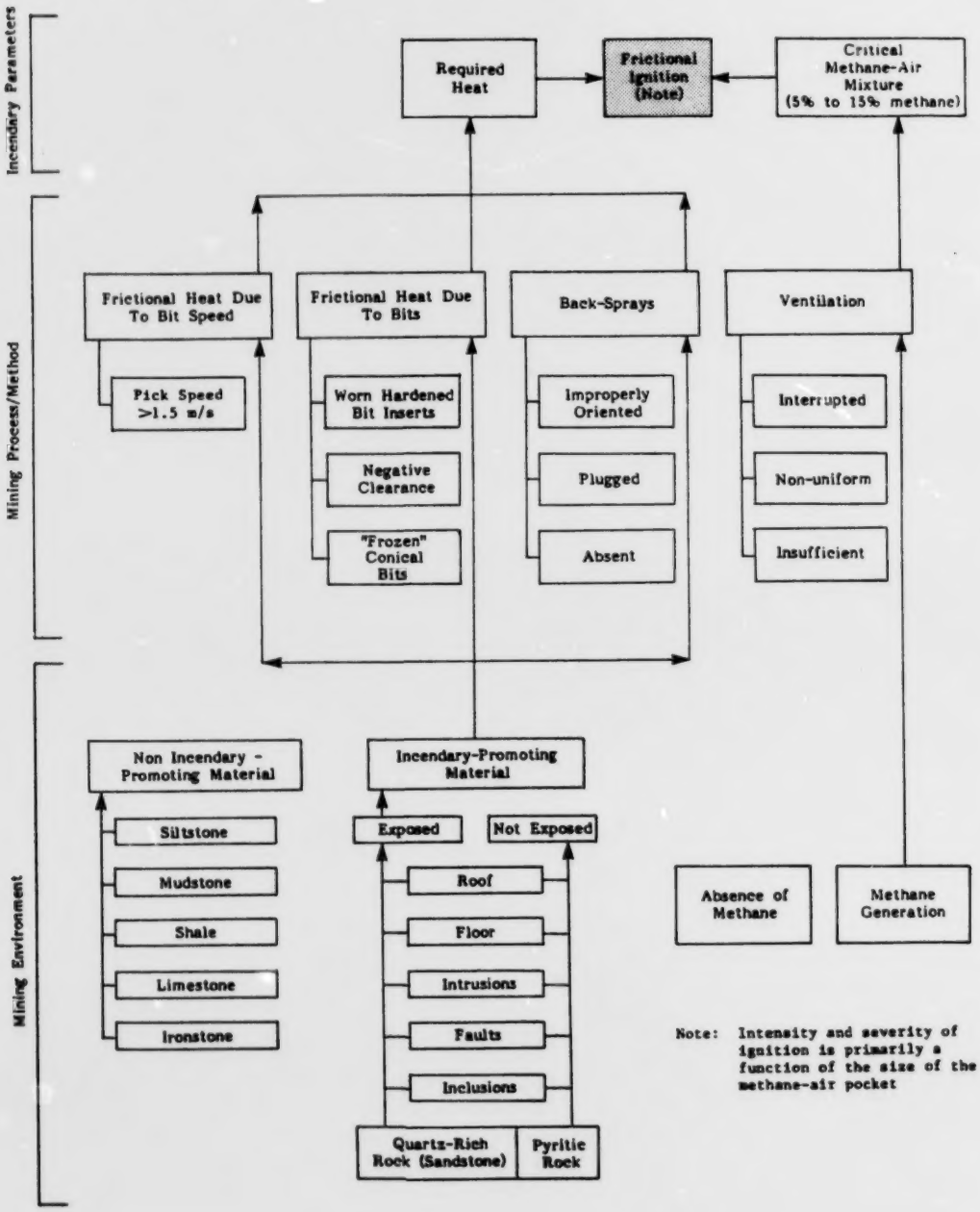
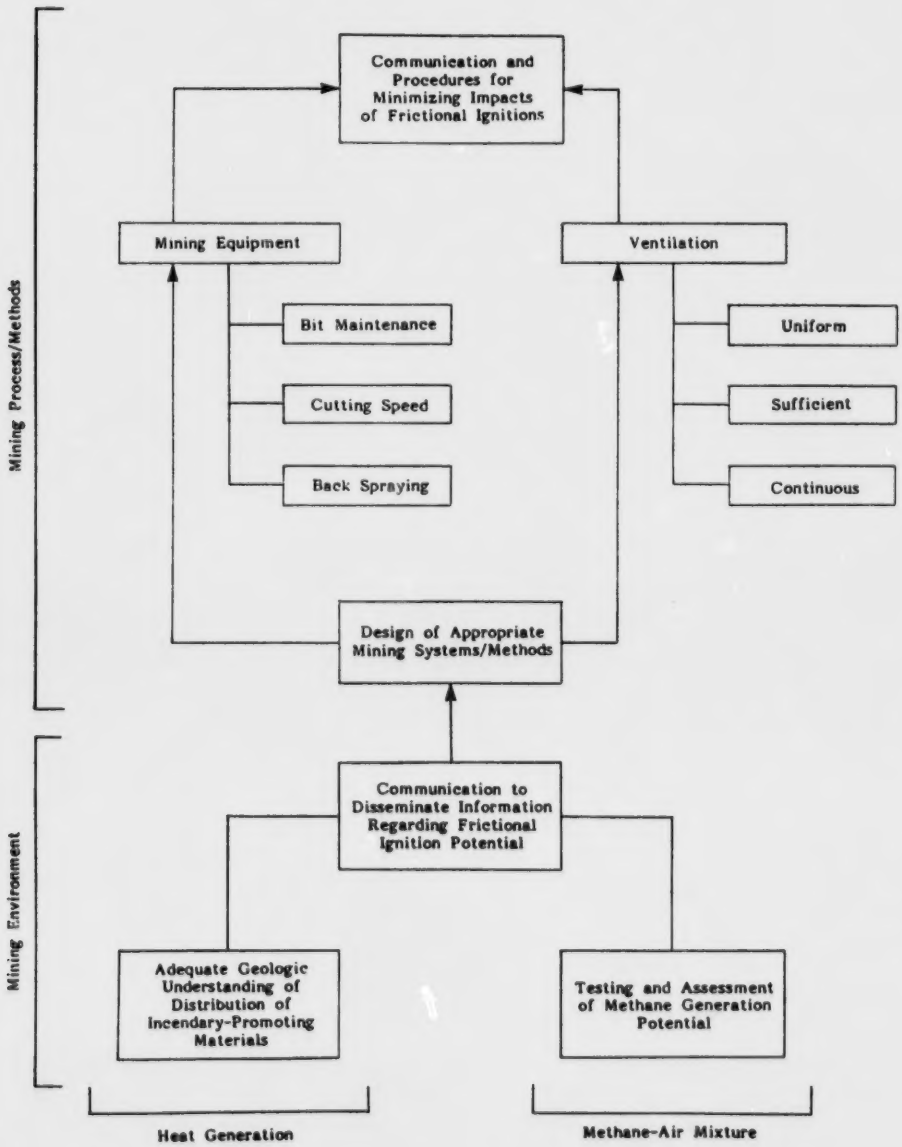


FIGURE 3-2
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

IDEALIZED MINING SYSTEM PARAMETERS FOR MINIMIZING FRICTIONAL IGNITION POTENTIAL



ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 4 - SYDNEY COALFIELD MINING OPERATIONS

Table of Contents

		Page
4.1	**Coalfield Development**	4-1
4.2	**Geology**	4-3
4.2.1	General	4-3
4.2.2	Prince Mine	4-3
4.2.3	Lingan Mine	4-6
4.2.4	No.26 Colliery and Glace Bay Project	4-8
4.2.5	Lingan-Phalen Project	4-10
4.4.6	Donkin-Morien Project	4-11
4.3	**Frictional Ignition Potential**	4-13
4.4	**Mine Layout**	4-13
4.4.1	Mine Geometry	4-13
4.4.2	Advance/Retreat	4-14
4.5	**Development**	4-14
4.5.1	Panel Development - Advancing	4-14
4.5.2	Panel Development - Retreating	4-15
4.6	**Extraction**	4-15
4.6.1	Mining Horizon	4-15
4.6.2	Face Length	4-15
4.6.3	Direction of Working	4-16
4.6.4	Power Supplies	4-16
4.6.5	Haulage and Transport	4-16
4.6.6	Drainage and Water Control	4-16
4.6.7	Face Equipment	4-17
4.6.8	Face Ends	4-18

.....Cont'd

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD DSS # 03SQ.23440-3-9187

SECTION 4 - SYDNEY COALFIELD MINING OPERATIONS

Table of Contents Cont'd

		Page
4.7	**Environment**	4-18
4.7.1	Main Ventilation	4-18
4.7.2	District Ventilation	4-18
4.7.3	Methane Drainage	4-19
4.7.4	Machine Ventilation and Dust Suppression	4-19
4.8	**Longwall Performance**	4-20
4.8.1	General	4-20
4.8.2	Face Performance	4-20
4.9	**Conclusions**	4-21

TABLES
(Following Text)

4-1 Sydney Coalfield Seam Sequence

4-2 No.26 Colliery Physical Properties of Rocks

4-3 Lingan-Phalen Project Physical Properties of Rocks

4-4 Donkin-Morien Project Physical Properties of Rocks

4-5 Lingan 5 West Longwall Face Profile

4-6 Lingan 8 East Longwall Face Profile

4-7 Lingan 9 East Longwall Face Profile

4-8 Prince 4 East Longwall Face Profile

4-9 Prince 5 East Longwall Face Profile

4-10 Face Performance - Lingan and Prince Mines

.....Cont'd

SECTION 4 - SYDNEY COALFIELD MINING OPERATIONS

4.1 COALFIELD DEVELOPMENT

The Sydney coal field has been in production over two centuries. The coalfield came into international prominence in the nineteenth century, supplying steam coal for ships plying the trans-Atlantic routes, and retained an important role until the 1920's. Between the two world wars, Government subsidies were necessary to support the industry, and a general run-down occurred until the mid-60's.

Following the establishment of the Cape Breton Development Corporation (CBDC) in 1968, and more particularly the oil price increases of the OPEC nations in 1973, the industry began to expand. The Lingan Mine was opened in 1973, and the Prince Mine opened in 1976/77. Currently, these two mines are operating. No.26 Mine has been closed following a serious fire in March 1984.

Three new mines are under development or active consideration - Lingan-Phalen, Glace Bay and Donkin-Morien. In this section of the report emphasis is placed on the two active and three proposed mines.

Longwall extraction systems have been continuously developed since 1951 when the 'DOSCO' Miner was introduced. This machine was cyclic with coal cutting on one shift, flitting the machine from the bottom of the face back to the top on the second shift and on the third shift advancing roof supports (wooden chocks or yielding props). The machine with a cutting height of 1.2 m to 2.2 m and cutting width of 1.5 m was mounted on crawler tracks and was unidirectional. It had a sump depth of 460 mm and its cutting head comprised a mat of

cutting chains. At first face belts were used and later armoured conveyors were introduced.

In the early 1960's an Anderson Boyes 52 kW trepanner was installed on 18 North face at Princess Colliery. The machine was equipped with two 860 mm diameter trepanning heads, a roof cutting disc to cut at heights from 1 m to 1.2 m, 2 shear jibs and 2 floor jibs. The machine was rope hauled and floor mounted in front of the armoured face conveyor. Roof support was by yielding friction props. The face conditions were difficult and included sandstone roof and low coal section and for these and other reasons, the installation was not successful.

In 1966, due to roof control problems brought on in part by the wide web of the DOSCO Miner and its cyclical operation, the Anderton shearer was introduced. The first machine was installed on 6 North face at No.20 Colliery on January 3, 1966. It was a uni-directional shearer cutting uphill, fitted with a plough. In November, 1968, a bi-directional single drum shearer fitted with a cowl was installed on No.28 West face at No.12 Colliery. Pick sprays were incorporated into this machine greatly reducing dust generation.

A single drum ranging shearer was installed on 17 North face at No.20 Colliery capable of extracting various seam sections. In October, 1969, the first double ended ranging drum shearer was installed on 18 North face, No.26 Colliery. It could cut a 2 m seam with 1600 mm diameter drums and was fitted with F I D D gear head for stable elimination. This type of shearer, manufactured by Anderson Strathclyde, is presently in use. Another model Anderson Strathclyde type 270 AMBROS with a 225 kW motor and fitted with a hollow shaft venturi is also employed.

Roof support techniques developed progressively from yielding props to frames, to chocks and most recently to shields which were introduced in 1978.

4.2 GEOLOGY

4.2.1 General

The rock mass in which alternative longwall facecutting system will have to operate in the Sydney Coalfield is a seaward thickening sedimentary wedge 50 km long, up to 15 km wide and from 0 to 1.2 km thick. The coal seam sequence within this rockmass is shown in Table 4-1.

Geologic and geotechnical characteristics define the environment in which any alternative longwall facecutting system must operate, and influence the design of longwall equipment and extraction procedures.

In this section the following mining areas and seams will be considered (Figure 4-1):

- Prince Mine, Hub Seam
- Lingan Mine, Harbour Seam
- #26 Mine, Harbour Seam
- Glace Bay Project, Harbour Seam
- Lingan - Phalen Project, Phalen Seam
- Donkin - Morien Project, Harbour Seam

4.2.2 Prince Mine

Prince Mine workings are in the Hub Seam. The mine was opened from the highwall of a small open pit on Point Aconi. Initial room-and-pillar extraction could not be sustained because:

- The bentonitic shale floor disintegrated under the mobile mining equipment

- The feather edge of a massive sandstone lens in the roof strata caused severe roof support problems.

Subsequently, the deeps were driven over 2000 m northward from the shoreline where the bedrock cover to the seabed exceeded 150 m; partial extraction was initiated by short, retreating longwall faces. The following description relates only to the longwall mining area (Figure 4-2).

a. Hub Seam

The seam varies in strike from 128° in the west through 110° near the deeps to 128° in the east; an overall dip of 3° northward is maintained. The coal cleat strikes 81°. A rider seam splits off the roof of the main seam to the north of the 0.2 m parting line shown on Figure 7-1. South of this line, in the east panels, the rider seam is included in the mining section; north of this line, only the main seam is extracted. The main seam thickens in the northern part so that an extraction height of 2.0 to 2.4 m is maintained generally. Where the major sandstone channel occurs, the Hub seam has been eroded locally leaving a seam as thin as 0.5 m.

b. Roof Strata

The strata overlying the Hub Seam is an interbedded succession of sandstone, siltstone and mudstones, ranging in thickness over the current mining area from 150 m to 215 m to the seabed. The immediate roof above the Hub Rider seam - southern area - comprises a mudstone about 1 m thick overlain by competent

siltstone. In the northern area, at some distance from the sandstone channel, a 2.5 m shaly mudstone unit forms the immediate roof, overlain by an interbedded succession of sandstones and mudstones. As the erosion channel is approached, the immediate roof is sandstone. This is usually the case in all west developments and the deeps. The sandstone is medium grained, crossbeded with carbonaceous material along bedding partings.

Tests on drilled core from Hole # PM 28 located at the west end of 2W Panel give the following results:

	Range	# Obs.	Average Strength MPa	Standard Deviation MPa
Unconfined Comp. Strength	20.3-45.7 MPa	11	30.5	7.5
Tensile Strength	1.2-2.9 MPa	7	1.8	0.6
Young's Modulus	6700-8100 MPa	2		
Poisson's Ratios	0.42	2		

The Ignition Temperature Potential (ITP, see Section 2.2) was not determined for roof strata. It is anticipated that the sandstone would have a high ITP and the mudstone a negligible ITP.

A study of jointing in the roof strata along the shore line indicates the presence of two equally prominent sets striking at 20^{o} and 105^{o}.

Drill Holes P5 and H12B (Figure 4-1) indicate that the immediate roof will be a mudstone/siltstone succession beyond the effect of the sand filled channel.

c. Floor Strata

A detailed study of the immediate floor, carried out by CBDC showed that the bentonitic shale encountered in the old room and pillar section thinned to less than 2 cm in the deeps at 1W Panel. The immediate floor in the current mining area comprises a competent siltstone and some sandstone over 2 m thick. Exploration Holes P6 to the north, and H12B to the west indicate that the siltstone floor is persistent. Exploration holes P5 and H12 to the northeast and east indicate a competent sandstone floor. Samples from these holes have not been tested for bentonite content. The ITP of the siltstone floor has been tested. The results (32% and 39% quartz greater than 5 um) indicate in intermediate ITP.

4.2.3 Lingan Mine

Lingan Mine workings are in the Harbour Seam. The mine is developed by arched deeps in the seam to a distance of 3.4 km from shore. Initially, under shallow cover to the seabed, coal was produced by room-and-pillar mining; after a solid bedrock cover of 250 m had been reached, advancing longwalls became the established mining method (Figure 4-3).

a. Harbour Seam

The strike of the seam is constant at $100^{o} \pm 4^{o}$ dipping northward at 6.5^{o} to 8^{o}. The cleat strikes 70^{o}. Recent operating faces show a seam thickness variation of 1.75 m to 2.25 m. Drillhole H1A located 2.5 km downdip shows a seam thickness of 1.9 m. This confirms the established Harbour seam continuity throughout the coal basin. Slight thickness variation due to sand filled scour channels exist throughout the mine.

b. Roof Strata

The Harbour seam near the current operating panels (7 East and 4 West) is overlain by about 490 m of interbedded sandstone, shales and siltstone to the seabed. The immediate roof is a competent mudstone with some siltstone partings. No rock strength determinations are available. A number of scour channels lie at or near the roof of the seam. These have been well documented by CBDC geology staff. Channels in the down dip extension of the Lingan Block are unpredictable, not only in their location, but especially in the depth of scouring associated with the channels.

The ITP of one channel was detailed along the 3W Panel maingate: The mudstones showed an ITP from 1.5% to 39% (negligible to intermediate) whereas the sandstones had a range from 52% to 79% (high ITP). In this particular case, the scour channels never got closer there 1 m above the seam.

A shoreline survey of joint orientations shows a single dominant set striking 90°.

c. Floor Strata

Generally, the Harbour Seam floor is a hard mudstone which forms a good mining floor. However, in the central and western parts of the current mining areas the immediate floor is a soft shale up to 0.5 m thick (Figure 4-3). Since the face equipment is not designed to operate on soft floors, this shale gives a high ash dilution.

The unconfined compressive strength of this soft floor has been estimated using the "NCB Cone Indenter," giving a range of 14

MPa to 44 MPa. Since no tests were run with this equipment on the competent mudstone floor, it is difficult to assess the difference between these floor strata.

One test was conducted on the ITP of the Lingan floor strata. It showed a negligible hazard at 13% quartz. The location of this test is not known.

4.2.4 No.26 Colliery and Glace Bay Project

No.26 Colliery workings in the Harbour Seam are the deepest in the coalfield. The mine is the only 'shaft' mine in the coalfield with recent workings over 7 km from shore. Advancing longwalls are the established mining method (Figure 4-4). Production was stopped in March 1984 due to a fire in the mine.

The Glace Bay Project is the planned down-dip extension of No.26 Colliery to 11 km from shore. It includes both the Harbour and Phalen seams, the latter will be excluded here. This project is in the planning stage and no actual development work has been carried out.

a. Harbour Seam

The strike of the seam in recent panels of No.26 is fairly constant at 102° ± 2°; dips vary from 6.5° to 11° northward. Near the limit of the Glace Bay Project, seam attitude varies from 85°, 7° N in the west to 110°, 6° N along the flank of the Bridgeport Anticline in the east. The cleat in the coal strikes 62°.

Seam thickness in the most recently mined panels varies between 1.8 m and 2.4 m. Seam thicknesses of 1.8 m and 1.9 m in Holes H1A and H2 respectively confirm the downdip continuation of the

seam. Sand filled scour channels have eroded the seam locally to less than 1 m in thickness.

Strength determinations for the coal were carried both by an on-the-spot core indenter and laboratory tests; they vary from 12 MPa to 24 MPa (Table 4-2).

b. Roof Strata

The strata between the Harbour seam and the seabed varies in thickness from 750 m at 14S Panel to 1150 m at the seaward limit of the Glace Bay Project. The immediate roof generally consists of competent mudstone to sandy shale. Sand filled scour channels occur at and near the roof of the seam. Recently these sandstones have shown a propensity for rock outbursts in single entry drivage. The cause for this phenomenon was being investigated by CBDC and CANMET prior to the mine fire.

Strength tests for siltstone and sandstone have been carried out (Table 4-2) but the common roof mudstone has not been tested. Although no tests for ITP are available for the roof strata, a high ITP must be expected wherever sand filled channels are encountered.

c. Floor Strata

The floor in No.26 Colliery is a competent, interbedded sequence of mudstones, shaly siltstones and sandstones. The immediate floor can be any one of these lithologies. A recent study by CBDC shows a distinct zonation of the ITP in the immediate floor of Panels 13S and 13N; it ranges from high in the east through intermediate near the deeps to negligible in the west

(Figure 4-3). Exploration hole H2 indicates a floor with negligible ITP.

Strength testing by 'core indenter' indicates a compressive strength of 23 MPa (Table 4-2); this seems to be a low value (cf. Table 4-4).

4.2.5 Lingan-Phalen Project

The Lingan-Phalen Project is planned to extract the Phalen seam about 150 m below the Harbour seam workings in the Lingan Mine area. The Phalen seam outcrops south of the Lingan Minesite (Figure 4-5). This project was approved for development in May 1984.

a. Phalen Seam

The strike of the seam is fairly constant at 100° dipping 12°N down to -600 m; below this level the strike varies between 90° and 110° with a generally shallower dip of 6°N. The New Waterford Anticline and Syncline axes trend across the resource block but the structural relief on these folds appears to be minimal.

The Phalen seam is 2.1 m to 2.3 m thick in the southeastern part of the resource block. A shale parting develops 0.9 m below the roof of the seam along a northeasterly line (Figure 4-5) and thickens towards the northwest, splitting off a rider seam. Figure 4-5 also shows the probable location of the 0.3 m isopach of this parting. West of the 0.3 m shale isopach the thickness of the main seam thins northward from 1.9 m to 1.2 m.

b. Roof Strata

The Phalen seam lies 150 m to 130 m below the Harbour seam; the interval thins slightly in a northerly direction. Generally a mudstone forms the immediate roof; onshore drilling indicates that this mudstone is relatively weak, but drillholes from the Lingan Mine and exploration hole H1A indicate a more competent nature. Drillhole C12, onshore, indicates that a sand filled scour channel may lie in the roof of the main seam, west of the zone where the rider seam splits off.

The results of limited strength tests on cores from the onshore drilling program are shown in Table 4-3. Although no determinations of ITP are available, a high ITP must be expected wherever sand filled channels are encountered.

c. Floor Strata

Mudstone forms the immediate floor in all intersections. Although the testing (Table 4-3) shows a very low strength, a very high Young's modulus is associated with these tests. These anomalous results of the testing leave some room to doubt the strength determinations. ITP was not determined, but should be negligible for the immediate floor.

4.2.6 Donkin-Morien Project

The Donkin-Morien Project is planned to produce coal from the Harbour seam and in the long-term the Hub and Lloyd Cove seams. Development is underway with the drivage of a 7 m diameter tunnel from Cape Perce. The Harbour seam should be reached early in 1985.

Exploration seismic work has indicated a major fold and overthrust structure in the eastern part of the resource block (Figure 4-6). Except for some minor thrust faulting in the old No.20 Colliery this is the only major fault structure indicated for the Harbour seam in the Sydney Coalfield.

a. Harbour Seam

Generally the seam strikes 90° to 100° dipping 8° to 5° northward. The overthrust/fold structure complicates this homoclinal structure in the eastern part. Seam thickness has been documented in eleven offshore drillholes. There is a general increase in seam thickness from 2 m in the west to 4 m in the east. Seam splits off the roof and floor account for some of the thickness variation. Although no scour channels were intersected in any boreholes, it is very likely that they exist in this resource block.

b. Roof Strata

The Harbour seam subcrops at the seabed. The bedrock cover to the seabed, therefore, varies from 0 m to an arbitrary limit of 1150 m. Harbour seam extraction is planned to start at 200 m to 250 m below the seabed.

The immediate roof is predominently a competent mudstone, which may be very thin where rider seams split off. The roof/coal contact tends to be pyritic.

Strength variations are shown in Table 4-4. The significant difference between 'core indenter' strength determination and proper core testing should be noted. Sand filled scour channels should be expected at Donkin-Morien. Tests for ITP were not available.

c. Floor Strata

The immediate floor is generally mudstone pyritic at the coal floor. Siltstones and fine grained sandstones have also been encountered. The floor should be competent (Table 4-4). ITP was not determined.

4.3 FRICTIONAL IGNITION POTENTIAL

The wide scale application of shearer loaders in the Sydney Coalfield has brought with it the problem of frictional ignition of methane-air mixtures by steel cutter picks impacting on quartzose rocks.

CBDC estimates the frictional ignition hazard by the National Coal Board Mining Department Instruction PI/1974/4 (Section 2.2).

Past experience in the Sydney Coalfield has shown that certain areas exhibit a higher potential for frictional ignition, in the roof and/or floor than others. It is not possible, however, to predict the potential hazard with any degree of certainty. The lithologic variation of the strata, particularly in relation to sandstone channels, is great.

Any longwall face at the active or proposed mines, therefore, may encounter roof or floor strata with a high potential for frictional ignition.

4.4 MINE LAYOUT

4.4.1 Mine Geometry

Present mine layout is based on a central system of dip (deep) developments from which longwall panels are worked with the roadways along the strike. Typically, the panels are at or near

right angles to the main dips, although the Lingan-Phalen layout envisages a panel alignment at approximately 60° to the main dips.

Typically, panels have long runs frequently in excess of 1000 m and in some cases up to 3000 m.

4.4.2 Advance/Retreat

The bulk of production from the Sydney coalfield has been from advancing workings. In the most recently worked mines, Lingan and #26, extraction has been exclusively by advancing, except for a single retreat panel attempted several years ago at #26 which was unsuccessful using the equipment and techniques then available. The first successful application of retreat mining was at Prince, where the first retreat face was established in 1979.

From a frictional ignition hazard reduction viewpoint, retreat working is advantageous and the next generation of mines - Donkin, Glace Bay and Lingan-Phalen - are all planned for retreat working.

4.5 DEVELOPMENT

4.5.1 Panel Development - Advancing

The intake and return roadways and face lines for advancing panels are developed by DOSCO roadheaders taking the coal seam and a roof brushing. Support is by RSJ arches for the gateroads. Face developments are driven square section and supported on girders and props.

4.5.2 Panel Development - Retreating

For retreat working at Prince, panel developments are driven by DOSCO dintheaders with a square cross-section taking the seam and occasionally a small floor brushing. The support is by RSJ girders on props.

4.6 EXTRACTION

4.6.1 Mining Horizon

In the Prince and Lingan workings, extraction is to the seam floor, although some floor rock is mined where exceptionally soft conditions prevail. Generally the whole seam is extracted up to the parting between the coal and the roof stratum. Where adverse conditions are encountered, it is common to leave a thin layer of roof coal to assist in optimising strata control. Extraction height is generally between 1.8 m and 1.9 m.

4.6.2 Face Length

The lengths of advancing faces at Lingan and #26 have been in the range of 150 m to 250 m with a trend towards longer faces. Considerations of seabed strain often require that sub-optimum face lengths be worked under shallow cover and at Prince this factor has dictated relatively short length faces, in the range of 50 m to 150 m..

4.6.3 Direction of Working

The faces are aligned between approximately 49° to 66° to the main cleat direction. The relationship between the face alignment and main cleat is as follows:

Mine	Face Alignment to Main Cleat
Lingan	57° and 66°
Prince	49° and 58°
No. 26	50° and 58°

4.6.4 Power Supplies

All present and proposed longwalls are provided with electricity at 550 or 1100 volts, compressed air at a pressure between 1000 kPa and 1500 kPa and a water supply.

4.6.5 Haulage and Transport

The coal conveying system presently in use and planned for future faces includes armoured face conveyors with capacities rated in at 600 t/h feeding 1060 mm gate belts via armoured stage loaders.

Materials handling to production panels is by diesel locomotive and/or endless rope haulage.

4.6.6 Drainage and Water Control

No major ingress of water is experienced on existing faces, nor is anticipated in the planned mines. Nuisance water is handled by local pump installations.

4.6.7 Face Equipment

All production faces employ conventional modern longwall systems. Brief specifications are provided in Tables 7-5 to 7-9.

All production is presently obtained from double ended ranging drum shearers. The machines at Lingan are typically Anderson Strathclyde 270 HP AMBROAS mechanically hauled machines. Two speed gear boxes provide drum speeds of 36 rpm and 55 rpm. The drum width is 760 mm and drum diameter 1500 mm to 1600 mm. The machines are fitted with pick face flushing and H.S.V. systems.

The Prince machines are 300 HP Anderson Strathclyde FIDD machines operating on Dynatrack chainless haulage. A single drum speed of 51 rpm is provided and drums are 685 mm wide x 1500 mm diameter.

All operating faces are currently equipped with Hemscheidt shields, either two-leg or four-leg. The Prince supports have a setting pressure of 24 MPa and a yield pressure of 33 MPa. The Lingan supports have a setting pressure of 26 MPa and a yield pressure of 33 MPa. Closed height of the shields is 1300 mm.

Armoured face conveyors by Dowty Meco, Huwood and Halbach and Brown are currently employed. Pan width is 732 mm, 762 mm or 764 mm and pan height 222 mm or 245 mm. Chain speeds are 1.06 m/s or 1.12 m/s. Chains are two-strand, typically twin outboard configurations.

4.6.8 Face Ends

Advancing longwalls in the Sydney Coalfield are worked without 'stables' and both ends of the faces are cut-out by the extended arm shearers. Roadway formation is practised in three general configurations - conventional behind the face, 'half-head' and 'in-line'. The retreat designs do not have stables or brushing.

4.7 ENVIRONMENT

4.7.1 Main Ventilation

All current and proposed mines in the Sydney Coalfield employ exhausting main ventilation. The total air quantity at Lingan Mine is 189 m^3/s and at Prince Mine is 73 m^3/s.

4.7.2 District Ventilation

The quantity circulated in each production district varies according to face conditions. Typical quantities for current faces are as follows:

Mine	Face	District Quantity (m^3/s)
Lingan	8E	31
	9E	24
	5W	32
Prince	4E	27

In the advancing sections in the Lingan Mine as a result of leakage through the goaf a considerable reduction in air quantity occurs between the outbye end of the district and the face. Quantities at the return end of the face and total quantity in the district of some Lingan faces are as follows:

Mine and Face	District Quantity m^3/s	Face Quantity m^3/s
Lingan 8E	31	18
Lingan 5W	32	21

On the retreat districts at Prince face and district quantities are essentially the same.

4.7.3 Methane Drainage

Methane drainage has been widely practiced on longwall panels in the Sydney Coalfield and is in use on all faces at Lingan and planned for all future faces, except those at Prince. Drainage is by the inclined borehole method with holes drilled from the return roadway into the roof over the longwall gob. Typical methane drainage rates are typically 0.2 m^3/sec pure methane at about 75% purity and 50% capture. Gas is piped out of the district and diffused into the main air flow in the return deeps. A project is currently in hand to extract methane and pipe it to the surface as useable product.

4.7.4 Machine Ventilation and Dust Suppression

All shearers currently in use in the coalfield have internal water sprays on the drums supplemented by external spray clusters. The Lingan machines are equipped with hollow shaft ventilators that provide a flow of air through the drum shaft to ventilate the back of the cut. Considerable efforts have been made by CBDC to optimize the delivery of water to the cutting area to provide maximum protection against frictional ignition.

4.8 LONGWALL PERFORMANCE

4.8.1 General

The production performance from longwall faces in the Sydney Coalfield is good by international standards. Where normal strata conditions prevail, shift and face performances have been achieved that are of world record standard. Average face performances over long periods are typically in excess of 2000 t/day of clean coal.

4.8.2 Face Performance

Results from three faces at Lingan and three faces at Prince provide an indication of the performance that will be required from any viable alternative longwall face cutting systems (Table 4-10).

Face production at Lingan, for example, averaged over 800 t/machine shift and the Prince 3 West face has established an average performance of more than 1000 t/shift. To achieve these average levels of production the face cutting system must have a capability of a shift performance well in excess of the averages achieved.

Actual face performance is significantly effected by factors such as roof conditions, floor conditions or strata irregularities. For this reason it is not possible to draw up quantitative general performance standards for future longwall faces. For the purpose of evaluating alternative longwall face cutting systems it

is considered that any candidate system must have the potential of producing at least 1500 t on individual shifts and must be capable of averaging in excess of 1000 t/shift.

Productivity from Lingan faces ranges between 16 t and 20 t/manshift. This figure includes all personnel in the district. Face productivity at Prince, which does not include the manpower used for development work, ranges between 34 t and 64 t/manshift. It is estimated that face productivity at Lingan, excluding outbye workers, is in the range of 35 t to 40 t/manshift. For an alternative longwall face cutting system to be competitive in terms of productivity it is estimated that it must have the potential of providing an average face OMS of at least 40 t/manshift.

4.9 CONCLUSIONS

In addition to the general requirements of frictional ignition hazard reduction considered in Section 3, the specific geologic conditions in the Sydney Coalfield and the mining systems currently employed or proposed define more precisely the design parameters for any satisfactory alternative longwall face cutting systems. Such a system must have the capability of:

- Cutting coal of medium hardness.
- Working on gradients generally up to about 12° to 14°.
- Working on a coal or soft fire clay floor.
- Cutting a floor at an intermediate horizon in the seam where necessary to improve conditions where the seam is underlain by soft fireclay, or to provide a cleaner product by selective mining.
- Forming a coal roof and not depending on free falling coal from a roof parting.

- Working in a retreat mode without the need to construct stables.
- Extracting a height generally 1.8 m to 2 m, ideally with the capability of working at heights as low as 1 m to 1.25 m to negotiate coal thinnings and up to 2.5 m to 3 m for use in the thicker sections anticipated in the Donkin Mine.
- Compliance with relevant statutory requirements regarding flameproofing and intrinsic safety and non-flammable hydraulic fluids.
- Compatability with AFC's and roof support currently used by CBDC.
- Performance of about 1500 t/shift and face productivities of 40 t/manshift.

The general parameters reviewed in Section 3 and specific parameters identified in this review of geology and mining operations are used to define the candidate alternative longwall face cutting systems reviewed in Section 5.

TABLE 4-1
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SYDNEY COALFIELD SEAM SEQUENCE

Seam	Coal Interval Thickness (m)	Interseam Thickness (m)
Point Aconi	1.0 - 2.0	
		70 - 90
Lloyd Cove	1.0 - 3.0	
		60 - 80
Hub Zone*(1)	3.0 -13.0	
		90 - 110
Harbour (2)	2.0 - 4.5	
		60 - 80
Bouthillier	0.5 - 1.0	
		20 - 40
Back Pit	0.5 - 1.0	
		30 - 35
Phalen (3)	0.5 - 2.0	
		40 - 60
Emery	0.5 - 1.5	
		130
Gardiner	0.5 - 1.5	
		330
Mullins	1.0 - 2.0	
		175
Tracey	1.0 - 2.0	

(After Haites, 1951; Forgeron, 1980; including Donkin-Morien data).
* May include up to 10 m of major rock partings

(1) Prince Mine and Donkin Morien Project (long term)

(2) Lingan and #26 Mines; Glace Bay and Donkin Morien Projects

(3) Lingan-Phalen and Glace Bay Projects

TABLE 4-2
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

NO.26 COLLIERY PHYSICAL PROPERTIES OF ROCKS

	Lith	I σ_c MPa	σ_c MPa	σ_t MPa	II E MPa	Poisson's Ratio
Roof	sltst	22-44				
	coal	12-19	17-24		3600	0.28
Floor mdst	mdst	23				
?	sltst		32-37			
?	ss		88	8		0.09

I strength estimate by Core Indenter

II Laboratory tests on core H/D Ratio = 2:1

σ_c unconfined compressive strength

σ_t indirect tensile strength

E Young's modulus

TABLE 4-3
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

LINGAN-PHALEN PROJECT
PHYSICAL PROPERTIES OF ROCKS*

	Lith.	c MPa	t MPa	E MPa	Poisson's Ratio
Roof	ss	29 - 72	5 - 7	14 500	0.1
	lst	38	11	20 000	0.3
	sltst	41	7	17 000	0.3
	mdst	20 - 36	6	17 500	0.6
	Coal	-	-	-	-
Floor	mdst	9 - 21	2	21 000	0.4

* Laboratory tests on core samples from onshore drillholes

c compressive strength
t tensile strength (method unknown)
E Young's modulus of elasticity

TABLE 4-4
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DONKIN-MORIEN PROJECT
PHYSICAL PROPERTIES OF ROCKS*

	Lith	I c MPa	c MPa	t MPa	II E MPa	Poisson's Ratio
Upper Roof	sltst	48	64-93	18-24	29 700	0.18
3 - 8 m	mdst		84	22	27 000	0.25
Lower Roof						
0 - 2 m	mdst	20-48	36-58	13-21	23 000	0.26
	coal	-	-	-	-	-
Floor	mdst	27-28	57-60	14-16	29 000	0.22
0 - 1.5 m	sltst		83	17	33 000	0.18

* Core samples from H8C and H8D tested by NCB 1978

I strength estimate by Core Indenter

II Laboratory tests on core H/D Ratio = 2:1

c unconfined compressive strength

t indirect tensile strength

E Young's modulus

TABLE 4-5
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

LINGAN 5 WEST LONGWALL FACE PROFILE

(Source: Cape Breton Development Corporation)

General

1. Name of Mine - Lingan
2. Name of Face - 5 West
3. Length of Face - 125.247 m

Supports - Run of Face

4. Manufacturer - Hemscheidt
5. Type - 2 leg shield
6. Setting Pressure - 4600 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

Supports - Face End

9. Manufacturer - Hemscheidt
10. Type - 4 leg chock
11. Setting Pressure - 3770 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. 4.133"

Pumps

14. Manufacturer - Hauhinco
15. Capacity - 30 gpm pressure 5000 psi
16. Location - Coal Level

Power Loader

17. Manufacturer - Anderson Strathclyde
18. Type - 270 A.M.B.R.O.A.S.
19. Type of Haulage - 22" Mechanical
20. Horse Power - 300
21. Height of M/C Base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 36 - 55 rpm
25. Drum Width - 30 ins.
26. Drum Dia. - 60 ins.
27. Number of starts - 3 - Forward attack and radial

TABLE 4-5 (Cont'd)
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

LINGAN 5 WEST LONGWALL FACE PROFILE

Face Conveyor

28. Manufacturer - Halbach & Braun
    Drive Frame - Halback & Braun Janel
    Gearbox - Halbach & Braun
    Pan - Halbach & Braun
    Chain - Reilloc
29. Pan Width 723 mm, Height 222 mm, Length 1500 mm
30. Gearbox Ratio - 39.33-1
31. Sprocket Teeth - 8
32. Chain Speed - 221 fpm
33. Chain No. of Strand - two
34. Chain Size - outboard 22 x 86 mm
35. Chain Crs. - 640 mm
36. AFC Capacity - 600 tons/hr
37. Motor BD HP. 140 Speed 1725
38. Motor TE HP. 140 Speed 1725

Stageloader

39. Length 100 - 150'
40. Width 30"
41. Speed (Chain) 254 fpm
42. Type - Huwood
43. HP. 140

Roadheader

44. Type Dimensions - Dosco Mark IIA Std.
    - Length 7400 mm
    - Height 1640 mm
    - Width 2858 mm
45. Boom Details - Trunk 2438 mm x 533 mm
    - Cutting head 50.8 mm x 50.8 mm
46. Motor - Hydraulic pump - 120 HP Cutting head 100 HP
47. Bridge Conveyor - 13.2 m plus - 3.35 m per intermediate
48. Excavation Details - 2.13 m x 1.83 m

Level Belt

49. 3 Huwood L-120 with 140 HP motors

TABLE 4-6
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

LINGAN 8 EAST LONGWALL FACE PROFILE

(Source: Cape Breton Development Corporation)

General

1. Name of Mine - Lingan
2. Name of Face - 8 East
3. Length of Face - 213.878 m

Supports - Run-of-Face

4. Manufacturer - Hemscheidt
5. Type - 2 leg shield
6. Setting Pressure - 4600 psi
7. Yield Pressure - 6300
8. Leg Dia. - 8.75"

Supports - Face End

9. Manufacturer - Hemscheidt
10. Type - 4 leg chock
11. Setting Pressure - 3700 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. - 4.133"

Pumps

14. Manufacturer - Hauhinco
15. Capacity - 30 gpm pressure 5000 psi
16. Location - Coal Level

Power Loader

17. Manufacturer - Anderson Strathclyde
18. Type - 270 A.M.B.R.O.A.S.
19. Type of Haulage - Mechanical
20. Horse Power - 300
21. Height of M/C Base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 36 - 55 rpm
25. Drum Width - 30 ins.
26. Drum Dia. - 64 ins.
27. Number of starts - 3 - Forward attack and radial

TABLE 4-6 (Cont'd)

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

LINGAN 8 EAST LONGWALL FACE PROFILE

Face Conveyor

28. Manufacturer - Huwood
    Drive Frame - Huwood
    Gearbox - Huwood
    Pan - Huwood
    Chain - Huwood
29. Pan Width 760 mm, Height 245 mm, Length 1500 mm
30. Gearbox Ratio - 40.94-1
31. Sprocket Teeth - 7
32. Chain Speed - 209 fpm
33. Chain Twin Inboard
34. Chain Size - 26 x 92 mm
35. AFC Capacity 600 tons/hr
36. Motor BE HP. 200 Speed 1800
37. Motor TE HP. 200 Speed 1800

Stageloader

38. Length 100 - 150'
39. Width 30"
40. Speed (Chain) 254 fpm
41. Type - Huwood
42. HP - 140
43. BJ.D. Stageloader PREPA 140 HP Motor

Roadheader

44. Type Dimensions - DP 200
    - Length 7400 mm
    - Height 1640 mm
    - Width 2400 mm
45. Boom Details - Trunk 2438 mm x 533 mm
    - Cutting head 50.8 mm x 50.8 mm
46. Motor - Hydraulic pump - 120 HP Cutting head 100 HP
47. Bridge Conveyor - 13.2 m plus - 3.35 m per intermediate
48. Excavation Details - 2.13 m x 1.83 m

LEVEL BELT

49. 1 Huwood L-120 with 140 HP motors

TABLE 4-7
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

LINGAN 9 EAST LONGWALL FACE PROFILE

(Source: Cape Breton Development Corporation)

General

1. Name of Mine - Lingan
2. Name of Face - 9 East
3. Length of Face - 214.274 m

Supports - Run-of-Face

4. Manufacturer - Hemscheidt
5. Type - 2 leg shield
6. Setting Pressure - 4600 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

Supports - Face End

9. Manufacturer - Hemscheidt
10. Type - 4 leg chock
11. Setting Pressure - 3770 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. - 4.133"

Pumps

14. Manufacturer - Hauhinco
15. Capacity - 30 gpm pressure 5000 psi
16. Location - Coal Level

Power Loader

17. Manufacturer - Anderson Strathclyde
18. Type - 270 A.M.B.R.O.A.S.
19. Type of Haulage - 22" Mechanical - Eicotrack Chainless
20. Horse Power - 300
21. Height of M/C Base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 36 - 55 rpm
25. Drum Width - 30 ins.
26. Drum Dia. - 64 ins.
27. Number of starts - 3 - Forward attack and radial

TABLE 4-7 (Cont'd)
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

LINGAN 9 EAST LONGWALL FACE PROFILE

Face Conveyor

28. Manufacturer - Dowty Meco
    Drive Frame - Dowty Meco
    Gearbox - Dowty Meco S200
    Pan - Dowty Meco
    Chain - Reilloc
29. Pan Width 764 mm, Height 222 mm, Length 1500 mm
30. Gearbox Ratio - 33.45-1
31. Sprocket Teeth - 7
32. Chain Speed - 206 fpm
33. Chain No. of Strand - 2
34. Chain Size - 22 x 86 mm
35. Chain Crs. 600.0 mm
36. AFC Capacity 600 tons/hr
37. Motor BE HP. 200 Speed 1800
38. Motor TE HP. 200 Speed 1800

Stageloader

39. Length 100 - 150'
40. Width 30"
41. Speed (Chain) 254 fpm
42. Type - Huwood
43. HP - 140

Roadheader

44. Type Dimensions - Dosco Mark IIA - DP 200 Dual Purpose Standard
    - Length 7400 mm
    - Height 1640 mm
    - Width 2858 mm
45. Boom Details - Trunk 2738 mm x 533 mm
    - Cutting head 50.8 mm x 50.8 mm
46. Motor - Hydraulic pump - 120 HP Cutting head 100 HP
47. Side Discharge
48. Excavation Details - 2.13 m x 1.83 m

LEVEL BELT

49. 2 Huwood L-120 with 140 HP motors

TABLE 4-8
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

PRINCE 4 EAST LONGWALL FACE PROFILE

(Source: Cape Breton Development Corporation)

General

1. Name of Mine - Prince
2. Name of Face - 4 East
3. Length of Face - 97.54 m

Supports - Run-of-Face

4. Manufacturer - Hemscheidt
5. Type - 2 leg shield - Compact design
6. Setting Pressure - 3500 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

Supports - Face End

9. Manufacturer - Hemscheidt
10. Type - 4 leg chock
11. Setting pressure - 3770 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. 4.133"

Pumps

14. Manufacturer - Peroni
15. Capacity - 30 gpm pressure 5000 psi
16. Location - Coal Level

Power Loader

17. Manufacturer - Anderson Strathclyde
18. Type - F.I.D.D.
19. Type of Haulage - 22" Mechanical - DYNATRACK Chainless
20. Horse Power - 300
21. Height of M/C Base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - 2
24. Drum Speed - 51 rpm
25. Drum Width - 27 ins.
26. Drum Dia. - 60 ins.
27. Number of starts - 3 - Forward attack and radial

TABLE 4-8 (Cont'd)
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

PRINCE 4 EAST LONGWALL FACE PROFILE

Face Conveyor

28. Manufacturer - Halbach & Braun
    Drive Frame - Halbach & Braun
    Gearbox - Halbach & Braun
    Pan - Halbach & Braun
    Chain - Halbach & Braun
29. Pan Width 732 mm, Height 222 mm, Length 1500 mm
30. Gearbox Ratio - 39.33-1
31. Sprocket Teeth - 8
32. Chain Speed - 221 fpm
33. Chain No. of Strand - 2
34. Chain Size - outboard 22 x 86 mm
35. Chain Crs. 640 mm
36. AFC Capacity 600 tons/hr
37. Motor BE HP. 200 Speed 1725
38. Motor TE HP. Nil.

Stageloader

39. Length 100 - 150'
40. Width 30"
41. Speed (Chain) 254 fpm
42. Type - Huwood
43. HP 75 - P100 Gearbox

Level Belt

44. 3 Huwood L-120 with 140 HP motors

TABLE 4-9

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

PRINCE 5 EAST LONGWALL FACE PROFILE

(Source: Cape Breton Development Corporation)

General

1. Name of Mine - Prince
2. Name of Face - 5 East
3. Length of Face - 121.92 m

Supports - Run-of-Face

4. Manufacturer - Hemscheidt
5. Type - 2 leg shield - Compact design
6. Setting Pressure - 3500 psi
7. Yield Pressure - 6300 psi
8. Leg Dia. - 8.75"

Supports - Face End

9. Manufacturer - Hemscheidt
10. Type - 4 leg chock
11. Setting Pressure - 3770 psi
12. Yield Pressure - 4640 psi
13. Leg Dia. 4.133"

Pumps

14. Manufacturer - Peroni
15. Capacity - 30 gpm pressure 5000 psi
16. Location - Coal Level

Power Loader

17. Manufacturer - Anderson Strathclyde
18. Type - F.I.D.D.
19. Type of Haulage - 22" Mechanical - DYNATRACK Chainless
20. Horse Power - 300
21. Height of M/C Base above top of Arc. - 91.5"
22. Length of Arms - 64"
23. Cowls - None
24. Drum Speed - 51 rpm
25. Drum Width - 27 ins.
26. Drum Dia. - 60 ins.
27. Number of starts - 3 - Forward attack and radial

TABLE 4-9 (Cont'd)

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

PRINCE 5 EAST LONGWALL FACE PROFILE

Face Conveyor

28.	Manufacturer	- Halbach & Braun
	Drive Frame	- Halbach & Braun Janel
	Gearbox	- Halbach & Braun
	Pan	- Halbach & Braun
	Chain	- Halbach & Braun

29. Pan Width 732 mm, Height 222 mm, Length 1500 mm
30. Gearbox Ratio - 39.33-1
31. Sprocket Teeth - 8
32. Chain Speed - 221 fpm
33. Chain No. of Strand - 2
34. Chain Size - outboard 22 x 86 mm
35. Chain Crs. 640 mm
36. AFC Capacity 600 tons/hr
37. Motor BE Nil
38. Motor TE HP. 2-140 Speed 1725

Stageloader

39. Length 100 - 150'
40. Width 30"
41. Speed (Chain) 254 fpm
42. Type - Huwood
43. HP 75 - P100 Gearbox

Level Belt

44. 3 Huwood L-120 with 140 HP motors

TABLE 4-10
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

FACE PERFORMANCE
LINGAN AND PRINCE MINES

Face	Operational Period	Total Production (t)	Shift Production (t)	Face OMS (t/ms)
Lingan 7E	Oct 20/80 - Aug 25/83	1 158 372	750	19*
Lingan 3W	Jul 06/81 - Feb 10/84	686 831	514	16*
Lingan 4W	Nov 02/82 - Apr 19/84	677 980	812	20*
Prince 3E	Sep 12/82 - Oct 25/83	425 122	614	36
Prince 2W	Feb 02/82 - Sep 10/82	187 782	571	34
Prince 3W	Aug 19/83 - Feb 16/84	279 586	1092	64

* Includes district manpower

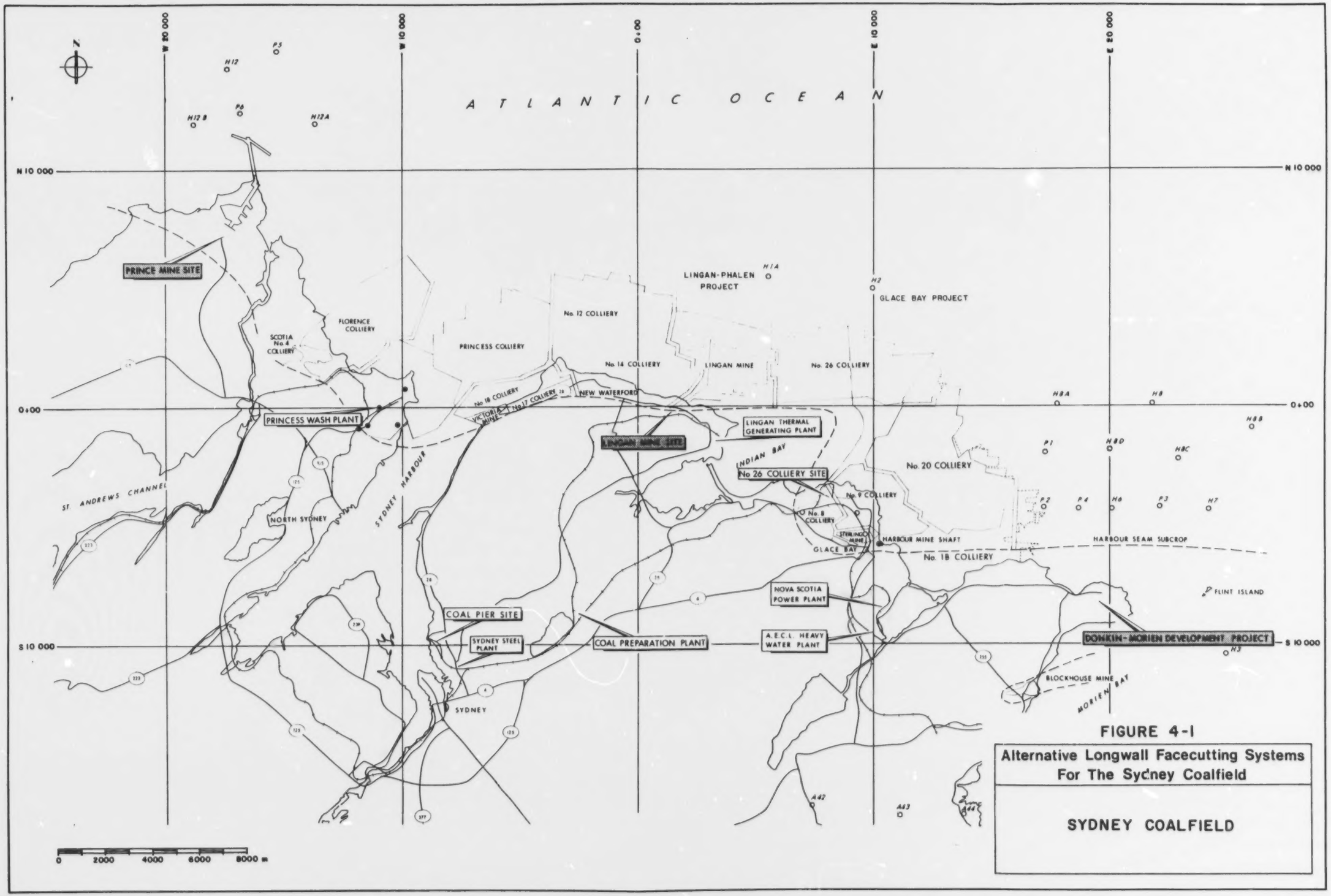


FIGURE 4-1

Alternative Longwall Facecutting Systems For The Sydney Coalfield

SYDNEY COALFIELD

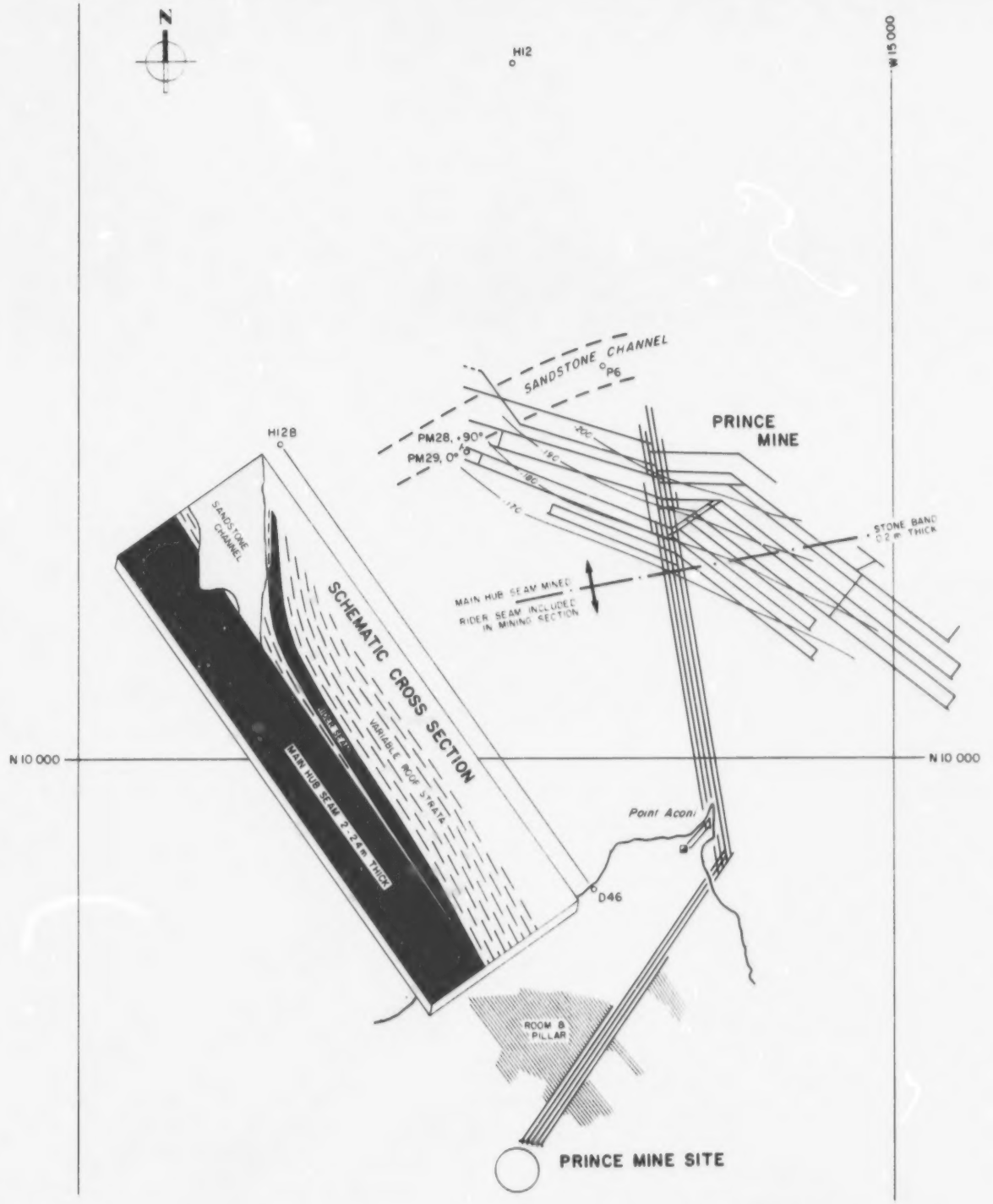
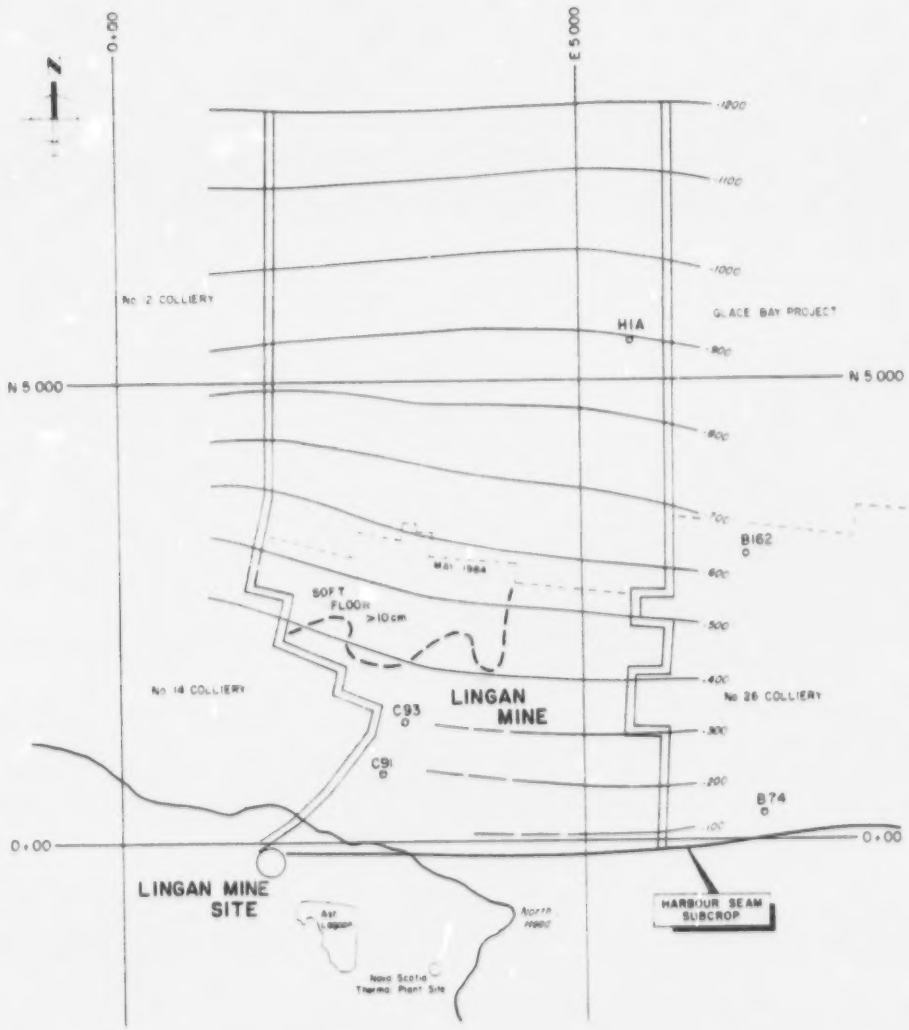


FIGURE 4-2

Alternative Longwall Facecutting Systems For The Sydney Coalfield

PRINCE MINE HUB SEAM



0 1000 2000 3000 4000 5000 m

FIGURE 4-3

Alternative Longwall Facecutting Systems For The Sydney Coalfield

LINGAN MINE
HARBOUR SEAM

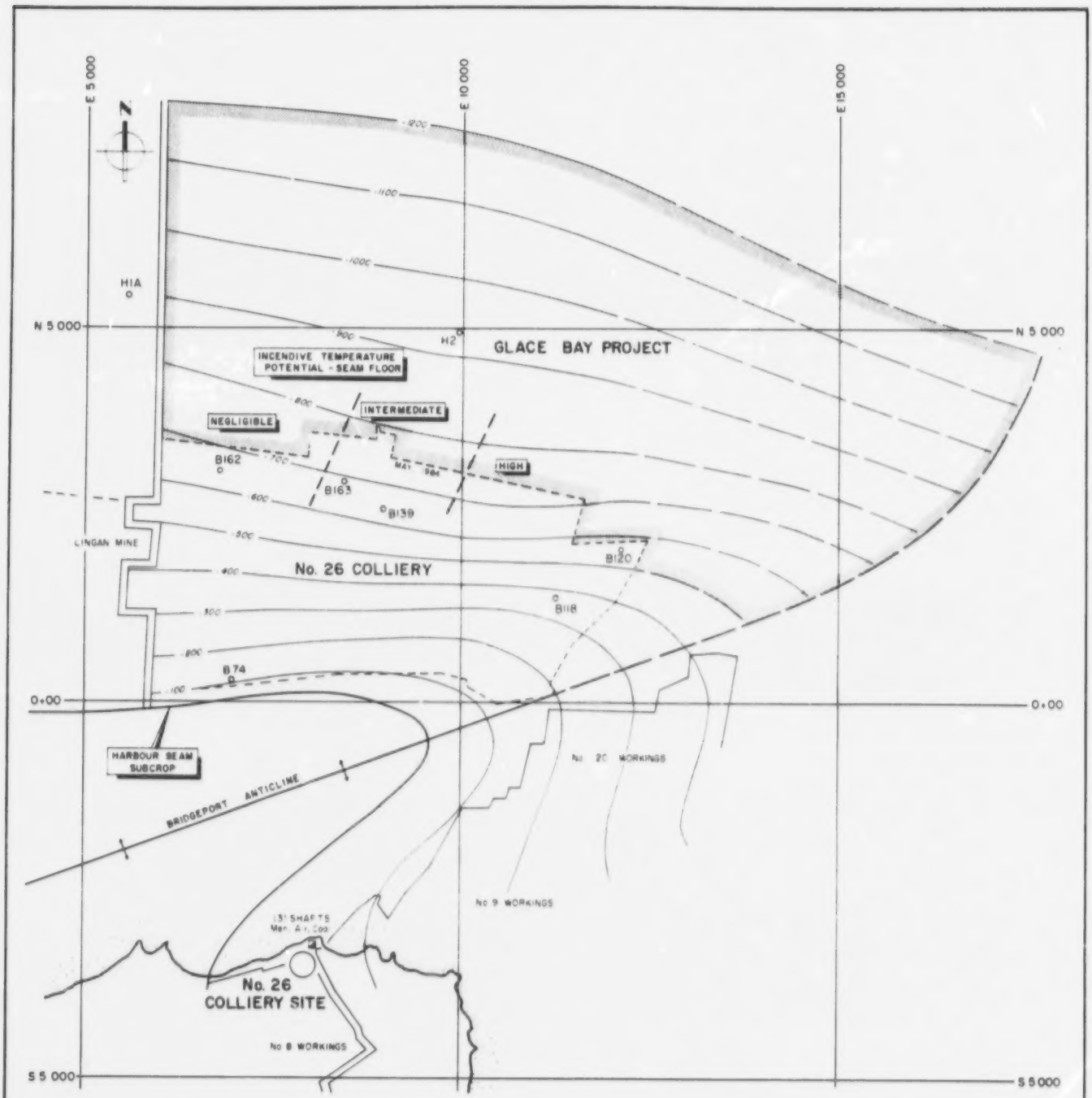


FIGURE 4-4

Alternative Longwall Facecutting Systems For The Sydney Coalfield

No.26 COLLIERY AND GLACE BAY PROJECT HARBOUR SEAM

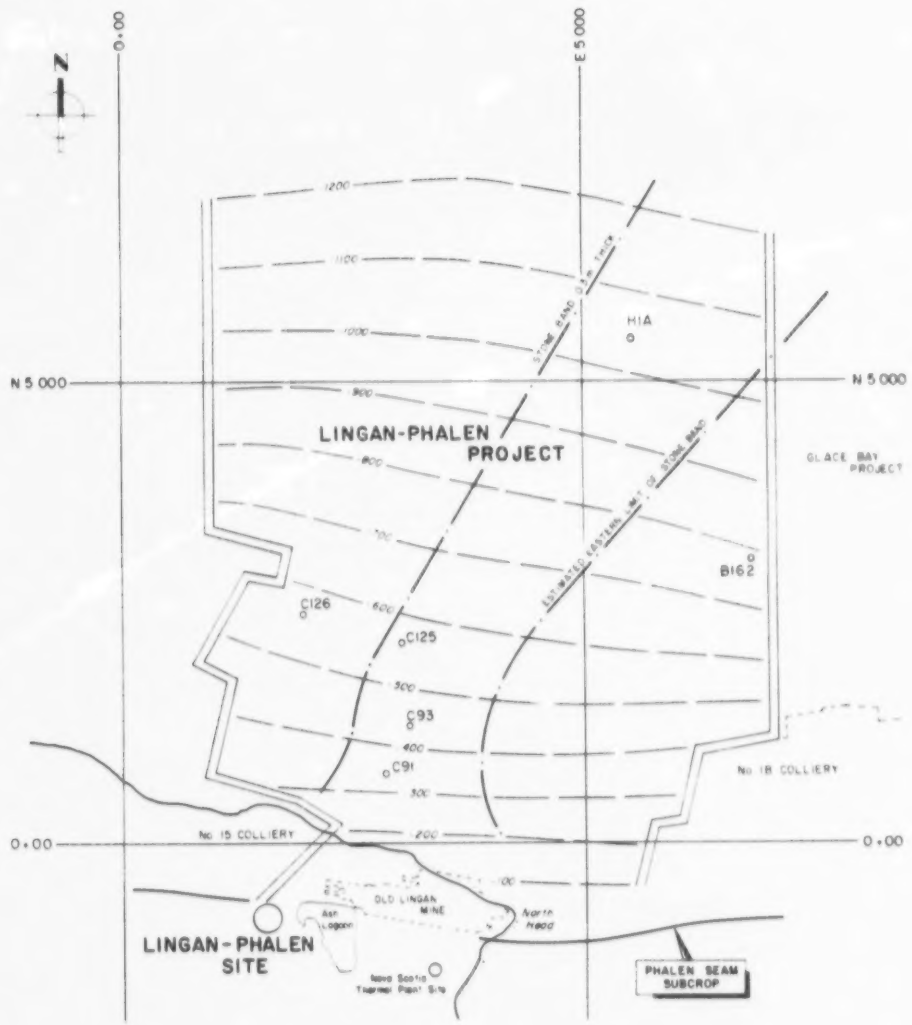


FIGURE 4-5

Alternative Longwall Facecutting Systems For The Sydney Coalfield

LINGAN-PHALEN PROJECT

0 1000 2000 3000 4000 5000 m

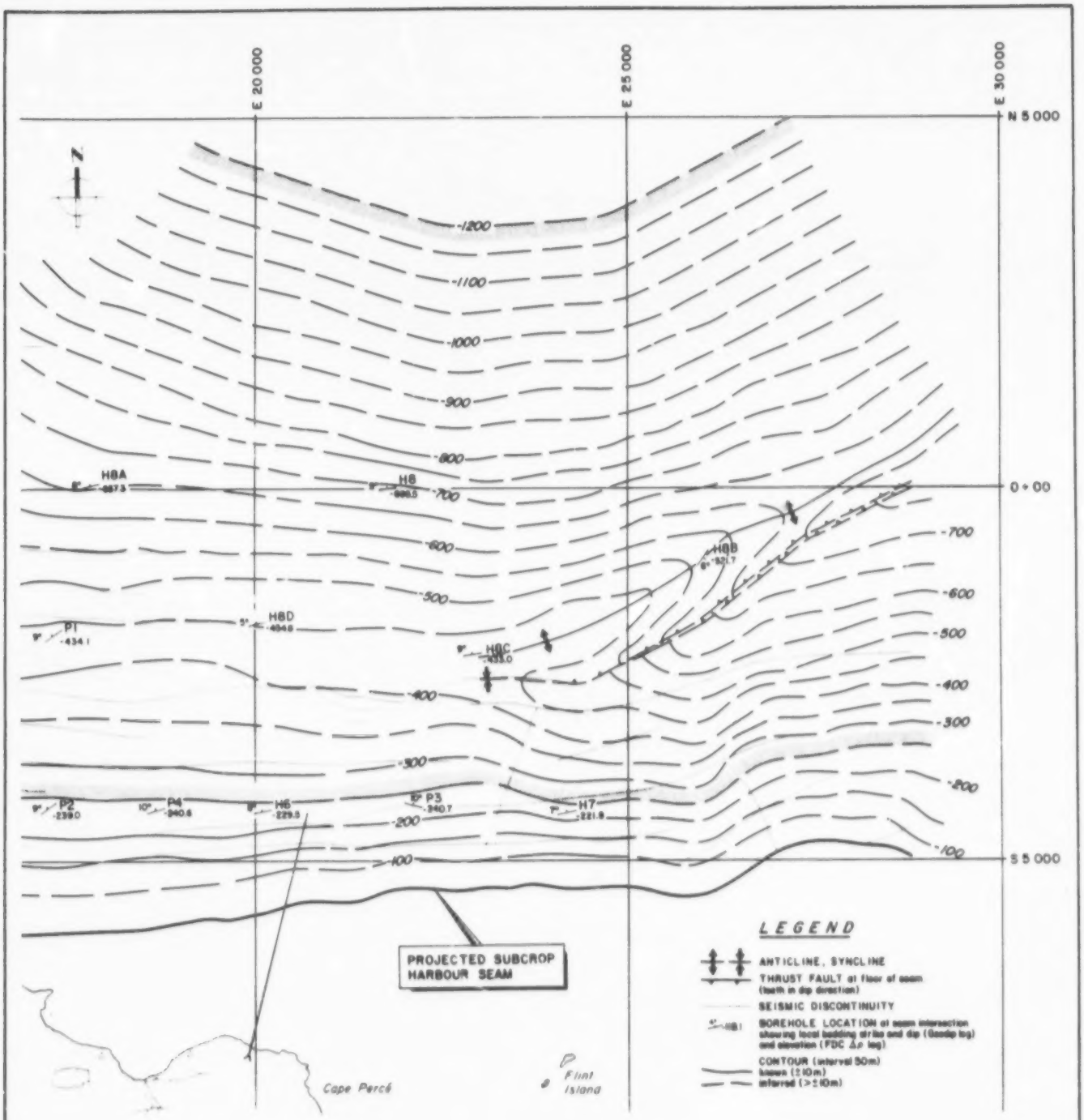


FIGURE 4-6

Alternative Longwall Facecutting Systems For The Sydney Coalfield

DONKIN - MORIEN PROJECT

HARBOUR SEAM

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 5 - REVIEW OF PAST, CURRENT AND EMERGING CONCEPTS

Table of Contents

		Page
5.1	Introduction	5-1
5.2	Early Mining Methods	5-1
5.2.1	Mining System	5-1
5.2.2	Cutting Methods	5-2
5.2.3	Face Conveyors	5-3
5.2.4	Loading With Chain Type Machines	5-3
5.3	Longwall System Development	5-7
5.3.1	Armoured Flexible Conveyor	5-7
5.3.2	Self Advancing Roof Supports	5-8
5.3.3	Advancing and Retreating Longwalls	5-8
5.4	Coal Ploughs	5-10
5.4.1	Introduction	5-10
5.4.2	Static Plough	5-11
5.4.3	Activated Ploughs	5-14
5.4.4	Water Jet Ploughs	5-17
5.5	Drum Cutters	5-17
5.5.1	Introduction	5-17
5.5.2	Vertical Drum	5-18
5.5.3	Horizontal Trepanning Drum	5-18
5.5.4	Horizontal Drum Shearer	5-22

.....Cont'd

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 5 - REVIEW OF PAST, CURRENT AND EMERGING CONCEPTS

Table of Contents Cont'd

		Page
5.6	Frictional Ignition Hazard	5-23
5.6.1	Background	5-23
5.6.2	Hazard Reduction	5-24
5.6.3	Emerging Concepts	5-25
5.7	Conclusions	5-25

FIGURES
(Following Text)

5-1 The Dosco Miner
5-2 Meco-Moore Cutter-Loader
5-3 Advance Headings
5-4 Retreat Longwall
5-5 Typical Plough Face Layout
5-6 Plough Installations
5-7 Huwood Slicer Unit
5-8 Longwall Trepanner
5-9 Early Anderton Shearer-Loader
5-10 Single Ended Ranging Drum Shearer
5-11 Double Ended Ranging Drum Shearer

SECTION 5 - REVIEW OF PAST, CURRENT AND EMERGING CONCEPTS

5.1 INTRODUCTION

This section reviews the concepts of extraction from an underground coal seam. The development of mechanized processes starting from early hand-mining methods to the current mechanized systems are described. The review indicates limiting factors, operational difficulties and levels of productivity associated with different systems and where possible provides the rationale for the process of development.

This review of past, current and emerging concepts provides the background from which to select systems meriting further consideration, and to identify areas where modifications to systems or equipment offer the potential for a reduction in the frictional ignition hazard.

5.2 EARLY MINING METHODS

5.2.1 Mining System

All mining involve the following inter-related activities:

- breaking the mineral from the solid face
- loading the broken mineral
- transporting the mineral from the face
- supporting the excavation
- maintaining an environment in which men and machines can operate safely.

Some of the activities may be combined by using machinery such as cutter-loaders.

5.2.2 Cutting Methods

Early hand mining of coal was accomplished by first cutting a horizontal slot in the solid coal by means of a hand pick followed by drilling shot holes and blasting down the overhanging coal.

The first step towards mechanization was the introduction of mechanical undercutting to replace the arduous and dangerous task of hand pick undercutting.

The first machines undercut the coal by means of punching action using compressed air to repeatedly punch at the coal face to cut the slot.

Later disc and bar undercutting machines used a shearing or sawing action. These machines both cut and cleared loose coal from the cut. The cutting was continuous and more efficient than punching machines.

The disc and bar cutters were eventually displaced by the more compact and versatile chain cutter, made up of four main sections:

- a haulage section, which incorporates a winching mechanism
- a motor section, which houses either an electric motor or a compressed air turbine
- a gear section, powered by the motor, which drives a sprocket engaged with the cutting chain.
- a cutting jib extending horizontally from the gear section.

As chain cutter designs improved and as higher horsepower machines were developed, the chain cutter was eventually able to undercut the coal to depths of up to 2.4 m although 1.4 m is

generally taken to be a standard cut or web. These machines did not perform any loading action.

5.2.3 Face Conveyors

In the late 1920's and early 1930's conveyors were introduced underground to transport coal away from the face. Three types were used:

- shaker pan
- scraper chain
- belt.

These conveyors were only about 25 mm above floor level for ease of loading. For ease of handling and more efficient use of available horsepower the belt conveyor became the most commonly used on longwall faces, although shakers and scraper chain conveyors were preferred on gradients.

5.2.4 Loading With Chain Type Machines

There were a variety of attempts to mechanize longwalls after about 1910 but it was not until after World War II that Britain, partly influenced by mechanized US practices, started to use the chain cutting machines as the basis for power loaders. Most notable among these machines were:

- the Waffler cutter-loader
- the Dosco Miner
- the Meco-Moore cutter-loader.

Waffler

The Waffler machine was an adaptation of a standard longwall undercutter to mechanically cut and load coal onto a face conveyor during a second pass through the face, after the coal had been blasted.

In very thin seams multi-jibs were used to take out the whole seam without blasting. Because of low productivity and reliability the waffler technique was not widely applied.

Dosco Miner

In the mid-1950's the Dosco Miner was developed and manufactured in Cape Breton, Nova Scotia. It was specifically designed to mechanize the longwall face operations of the Cape Breton coal mines.

The machine was mounted on crawler tracks; it had a cutting head made up of seven parallel cutter chains, which could be raised and lowered by hydraulic pistons. Figure 5-1 illustrates the machine and its application.

Coal cut by the chains was carried back from the head and dumped onto a short, transverse belt conveyor, which transferred the coal onto the face chain conveyor.

The machine was electrically powered through gear-boxes and hydraulic system. It was capable of cutting any hardness of coal, but due to its dimensions, was limited to seams between about 1 m and 2.5 m thick.

The machine started cutting at one end of the face removing a 1.5 m web of coal until the other end of a 200 m face was reached. Temporary supports were set as the machine advanced, followed by extensions of the permanent supports.

When a cut was completed the machine had to return through the face to start the next cut, but before recommencing cutting the conveyor had to be moved over.

Although effective as a cutter-loader, the system was cyclic and required the preparation of a stable at one end of the face. It was not suitable under weak roof and even under competent roof considerable moving and resetting of supports was necessary. The Dosco was superceded by the development of the more versatile and productive shearer.

Meco-Moore

The Meco-Moore cutter-loader consisted of chain cutters and a loading section (see Figure 5-2). The coal face was cut by two horizontal chain cutter jibs to a depth of 1.4 m. These cuts were followed by a third vertical shearing jib. The coal parted from the roof and broke up as it fell onto a fast moving, ribbed loading conveyor, which carried the broken coal with enough velocity to project it onto the face conveyor belt.

The machine was used extensively in seams above 1.25 m thickness and generally up to 2 m thickness.

While the Meco-Moore was a major advance over hand filling, its effective use required good roof conditions since a large area of roof (approximately 10 m^2) was exposed before new supports could be set. Other operational problems were its cumbersome

nature and the fact that its jib cutting section and loading/shearing section had to be separated, crossed over and reconnected at each end of the face to prepare for cutting back the other way. This required the pre-preparation of an excavation ahead of the coal face, called a stable, in which the machine turn-round could be accomplished.

Where the Meco-Moore was able to work it was considered very much more productive than the undercut, hand-filled faces. The unit produced lumpy coal and, in fact, its propensity to discharge very large lumps of coal onto the face conveyor was a cause of many operational delays and frequently led to extra persons being assigned to break lumps.

The era of the chain type cutter-loaders, as applied to longwalls, persisted into the 1960's but by then other forms of mechanized face cutting were being developed, including plough machines which exerted a wedging action to break off the coal.

The most important features of the chain type cutter-loaders were also their major disadvantages, these were:

- the mining system was cyclic, production had to stop so that conveyors could be moved into the next row of supports
- the cut or web removed from the face was the traditional 1.4 m. In many cases this left open a large area of roof which led to problems of roof support
- it was necessary to prepare stables at each end of the face to permit machines to be turned around or, alternatively the machine would only cut one way and then had to return to its starting point for each cutting cycle to re-commence
- the increased number of cutting chains (with a chain invariably cutting at floor level) led to an increase in the number of frictional ignitions in the cut.

5.3 LONGWALL SYSTEM DEVELOPMENTS

5.3.1 Armoured Flexible Conveyor

During and after World War II German engineers increasingly applied the concept of breaking and loading coal from longwalls using ploughs. The plough wedged coal off the face in thin slices and loaded it onto a face conveyor located next to the face.

To use coal ploughs it was necessary to provide a continuous, plough guiding [illegible], between the coal face and the supports, throughout the length of the face. The conveyor was used as the guide and, therefore, had to be strongly built of heavy steel sections in order to be able to withstand the very high forces applied to it by the plough action and the plough hauling system. To meet these requirements the 'Panzer' conveyor was designed. This consisted of a link chain scraper conveyor running in a shallow trough formed by armoured steel conveyor sections, each 1.5 m long. Electrically powered drive units were used to drive the scraper chain. The conveyor sections were loosely connected so that the conveyor was flexible and could be 'snaked' forward by means of pusher rams while the conveyor continued to run and carry coal.

The 'Panzer' conveyor evolved to become the armoured flexible conveyor (AFC) which is now an integral part of modern mechanized longwall installations. The development of the AFC was a major advance in mechanized longwall mining techniques. Traditional concepts were re-assessed:

- the traditional 1.4 m wide web was no longer necessary to attain high productivities. Narrow web systems were perceived as a means to improve roof control

- cutter-loaders could be used on a prop-free-front with the conveyor right up to the face
- conveyors could be moved forward without dismantling and re-erection.

The introduction of the AFC made non-cyclic mining possible and the development of continuous longwall mining became a realizable goal.

5.3.2 Self Advancing Roof Supports

The hydraulic rams used to push over or snake the AFC originally used a steel bar jammed into the roof as the anchor from which to push. Hand pumped hydraulic props replaced the rigid and friction yielding props which were set under steel bars to support the roof.

Roof support using individual hydraulic props , in turn, led to the development of hydraulically operated support units. This support method has been developed to a high level of reliability so that the mechanism for advancing both conveyor and supports is an integral part of current mechanized longwall installations.

5.3.3 Advancing and Retreating Longwalls

The rate of advance of mechanized advancing longwalls increased as cutter-loaders became more powerful and productive. The preparation of stables and machine turn round time at each end of the face became an obstacle to continuously producing face machines. It was increasingly difficult to have face-end stables completed before the cutter-loader had completed its face run. In the thinner seams, the roadways at the face end had to be advanced by taking down rock for extra height. Again there were

difficulties in completing these tasks within the time-frame of the cutting run through the face.

To overcome these difficulties two methods were used:

- increased face lengths
- advanced roadway headings.

Increasing the face length provided more time to complete the face-end tasks before the cutting machine arrived. Face lengths gradually increased from the early 100 m to as much as 250 m. However, this led to problems of powering face conveyors and as many as four 50 kW drive units were employed to power a single face conveyor.

Advanced roadway headings consist of driving the face end roadways in advance of the face line by a distance of some 15 m to 25 m (see Figure 5-3).

The use of advance roadway headings:

- enables roadway drivage to be done independently of face operations
- uses the width of the roadway as part of the face-end stable so that there is less stable to be excavated during each machine run.

The improvements in underground mining machinery have greatly increased the rates at which underground roadway development headings can be driven. Headings can now often be driven profitably or at a 'break-even' cost and retreat longwall faces are becoming more frequently employed (see Figure 5-4). In the retreat longwall system the roadways are driven out first until they reach their furthest extent. The face line is developed and

the longwall equipment installed. The face is then retreated back from its furthest point. By doing this:

- there is no conflict between roadway drivage and face operations
- the stables, if needed, can utilize the width of the roadways
- access tunnels to the face are in solid ground and usually easier to support and maintain
- there is no ventilation leakage across the gob so that face ventilation is improved
- equipment and machinery is transported to the new face through well supported roads. Conversely, equipment withdrawn from faces does not have to be transported through roadways which have suffered convergence damage as is frequently the case in advancing longwalls.

At the same time as these developments were taking place, cutter-loaders were also improving.

The coal plough and ploughing techniques improved; the chain cutter principle continued to be extensively used and a variety of drum type cutters were developed. Further advances towards continuous mining continued with the development of bi-directional cutter-loaders and methods of eliminating the need for face-end stables.

5.4 COAL PLOUGHS

5.4.1 Introduction

The coal plough offers a very simple concept of cutting and loading coal from the longwall. In its basic form, ploughing consists of using chains to haul a steel, toothed, wedge-shaped block back and forth through the face. Coal extraction depends on two actions:

- Applying enough force on the plough to move it through the face with its teeth embedded in the solid coal. The teeth impart a wedging/prying action to peel off a thin strip of coal, about 50 mm thick.
- Using the plough-like shape of the steel block to scoop up the loosened coal and turn it onto the conveyor.

Development of the plough principle has resulted in three types of plough cutter-loaders:

- The static plough, which relies on the direct force of the teeth to break the coal.
- The activated plough, in which the wedging action of the teeth is assisted by movement of the teeth in either a vibratory or an oscillating sawing action.
- The water jet plough using high pressure water jets to fracture the coal and assist the cutting action.

5.4.2 Static Plough

The static plough consists of a massive block of steel segments bolted together to form the plough body of the required shape for loading coal onto the conveyor as it traverses the face. The plough is hauled through the face line by means of a chain driven by haulage units incorporated into anchor stations at each end of the face. The anchor stations are secured by hydraulic jacks which tighten up to the roof. The chains run in protective guides which form part of the conveyor structure. A typical plough face layout is shown in Figure 5-5.

The wedge shaped plough body has a series of specially hardened, chisel shaped, replaceable teeth, at each end of the plough so that it can cut in either direction.

The plough body runs on the floor stabilized by guide shoes which run on both edges of the conveyor structure, sometimes passing underneath the structure and sometimes over the top, depending on the particular model of plough. Figures 5-6 illustrate the two types in operation on a modern longwall. The self-advancing powered supports provide the necessary solid anchor from which the conveyor rams push to hold the cutting teeth of the plough tight to the coal face.

The cutting action of plough teeth is mechanically complex, affected greatly by seam characteristics such as:

- distribution of banded constituents within the seam section
- roof pressure on the coal face
- direction of cleat relative to the face line
- readiness of coal to part from the roof strata and, to a lesser extent, from the floor.

The cutting action of plough teeth can be considered as comprising three elements - peeling, kerving and shattering.

The beginning of detailed research into the cutting action of picks, stemmed from efforts to improve the performance of static ploughs.

The advantages of the static plough are that it:

- produces a high proportion of +50 mm size coal
- has no electric power cables trailing the plough
- is suitable for cutting and loading in thin seams
- aids roof control by cutting in small increments
- produces little dust
- presents a low frictional ignition hazard due to the slow speed of the picks and the well ventilated shallow cut.

The disadvantages of the plough are related to:

- poor stability, especially in the presence of soft floors; this is worsened when there is hard coal at the bottom of the seam
- difficulty in controlling cutting horizon; no satisfactory methods of automatic horizon control have been developed
- difficulty in maintaining straight face alighment
- poor productivity in hard coal
- inability to leave a coal roof where weak strata overlies the coal.

Static coal ploughs can be applied under the following conditions:

Face gradients:	level to around 70°
Seam thickness:	0.65 m (min.) to about 2.0 m
Top coal:	must part readily from the roof
Bottom coal:	preferably softer than the upper parts.

Mechanical aspects of the plough are:

Length of plough body:	from 1.8 m to 4.2 m depending on the model
Weight of plough body:	from about 1 t to as much as 10 t depending on the model
Power of hauler:	15 kW min. to 530 kW depending on model and application
Ploughing speed:	normally 1.8 m/s but can be as low as 0.75 m/s
Face length:	normally about 200 m
Depth of cut:	from 50 mm to a maximum of 155 mm
Blades or picks:	usually chisel type approximately 50 mm wide
Haulage force at the plough:	4 t - 7 t (mean) 7 t - 11 t (peak)

Note: Overloading of the haulage system is prevented by the use of shear pins in the hauler unit. A great deal of coal cutting time can be lost due to pins shearing and the plough sticking in hard coal.

Productivity varies depending on face length, coal hardness and seam thickness. For example, at a seam thickness of 1.5 m a production of 500 t/shift might be expected with peak production at about 250 t/h.

Many trials have been conducted with ploughs to improve their reliability of performance including hydraulic equalizing of the pick loading to obtain automatic variation of pick penetration.

Although ploughs continue to be used, particularly in Germany, they are generally employed in thin seams, hence their production levels tend to be low. The availability of low seam shearers and the trend towards mining only the thicker, more economic seams, has led to the decline in the number of operating plough faces.

5.4.3 Activated Ploughs

Attempts were made to improve plough performance by imparting a percussive movement to teeth of the plough, mainly to enable ploughs to be used in harder coals. The Schnellhauer and Hannibal Hewer ploughs of German manufacture, were the most notable of this type. These ploughs did not prove satisfactory due to the tendency for the teeth to become embedded into coal so that the haulage was constantly being overloaded.

Other machines operating on the plough principle were developed. The Samson stripper used a combination of hydraulic jacks and rams to drive a wedge into the coal to remove a 610 mm web. It produced reasonable results in suitable conditions but was soon superceded by more productive machines such as the Huwood Slicer loader.

The slicer is a double ended, wedge shaped activated plough. It has teeth which oscillate in a circular motion to 'saw' the coal at the leading edge of the wedge as it removes a 355 mm slice from the face. The plough section runs along the floor, partly supported by a frame which straddles the AFC structure. Mounted on the frame and over the conveyor is a motor section,

which powers the moving cutter teeth. The machine is made to traverse back and forth across the face by means of a sprocket on the slicer unit which engages in a 'dead' chain anchored at each end of the conveyor. In harder, thick seams the work load of the slicer is reduced by using a chain cutter to pre-cut the coal. The cutter is also mounted on the conveyor and can be attached to the main frame of the slicer to form a single unit. The length of the cutting jib is designed to ensure that the coal is always pre-cut to a minimum depth of one slice (355 mm) after the slicer has passed. The horizon of the pre-cut is selected to suit the conditions of the particular installation; it is usually in the hardest coal.

The Huwood slicer proved to be a very productive machine and was in use up to the early 1970's when it was operated on faces equipped with self advancing hydraulic supports, notably at Maltby Colliery in the NCB South Yorkshire Area. Its production capacity was comparable to that of the shearers operating at that time. The main disadvantages of the slicer were:

- when it was used with a separate pre-cutter the system was semi-cyclic. This problem was overcome when the cutter and slicer were combined into a single unit as shown in Figure 5-7
- slicer operations required the preparation of face-end stables
- the slicer was not designed to cut through hard roof and floor strata and was, therefore, not well suited to negotiating minor faults and thick, hard, dirt bands
- it did not operate well on very soft floors and had no horizon control mechanism
- its operation depended on top coal parting readily from the roof; furthermore, it was not equipped to cut leaving a coal roof
- its productivity was related to the combined effect of coal hardness and direction of cleat.

The advantages of the slicer were:

- it was a simple but productive machine producing a high proportion of + 50 mm size coal
- it did not create serious dust problems
- the depth of web or slice was 355 mm which could be well ventilated
- where a pre-cutter formed part of the slicer unit, the cut was shallow and reasonably well ventilated. The pre-cut could, if necessary, be placed to avoid horizons which presented a known frictional sparking hazard and was not normally placed at floor level where frictional sparking commonly occurs
- the shallow depth of the slice permits the face to be advanced in small increments which can often help in gaining satisfactory support in the presence of weak roof strata.

The slicer can be applied in the following conditions:

Face Gradients: Level to 15°. The slicer has not been tried on severe gradients but there are no serious technical reasons why the slicer principle should not be applied on gradients steeper than 15°.

Seam Thickness: Preferably not less than 1.2 m and not more than 2.4 m. The lower limit is related to machine size and lump clearance between the machine and the coveyor; the upper limit is related to the readiness of top coal to part from the roof as well as to the vibration and stability problems that might be expected where the cutting teeth reach to a height exceeding 2.0 m.

Face Length: Nominally 200 m but limited by the conveyor rather than the slicer.

Depth of Cut: 255 mm to 356 mm.

The mechanical features of the slicer are:

Length across cutting teeth:
Weight of the slicer (excluding pre-cutter):
Maximum traversing speed: 4.5 m/min
Both electric and compressed air slicers are available
Motor Power, (excluding pre-cutter): 37 kW to 56 kW
Rate of teeth occillation: 3 cps

Amplitude of oscillation: 40 mm

Productivity of the slicer depends on face length, seam characteristics and seam thickness. Actual production capacity from a 2.13 m seam was about 850 t/shift taking 6 slices per shift.

The slicer was eventually replaced by the shearer more for reasons of standardization of equipment than for operational shortcomings of the slicer. At no time was the slicer associated with a frictional ignition hazard and the use of a compressed air driven version persisted into the 1970's at a gassy mine where the use of electricity was not permitted on the faces.

5.4.4 Water Jet Ploughs

Ploughs incorporating high pressure water jets have been developed in Germany and the USA. The principal types are the GHH Jetminer, the Westphalia Hydrohobel and the University of Missouri, Rolla (UMR) Hydrominer. The principles used in these machines have considerable potential for development of alternative facecutting systems and the equipment is described in detail in Section 6.

5.5 DRUM CUTTERS

5.5.1 Introduction

The effective use of drum cutters depends on their ability to load as well as cut the coal. Three arrangements of the drum's rotational axis have been used:

- axis vertical
- axis horizontal and parallel with the conveyor.

- axis horizontal and at 90° to the conveyor

In each case cutting picks are arranged in a pattern around the drum so as to bite into the coal as the drum rotates moving progressively along the face. There is a design relationship between the number of picks, pattern of pick arrangement, speed of rotation of the drum and speed of lateral movement of the drum.

5.5.2 Vertical Drum

The vertical drum arrangement was tried in the late 1940's. The horizontal cross-section of the drum was star shaped with the picks mounted on the vertical ribs at the points of the star. The star shape also formed paddles. After being cut, the loose coal was loaded by the action of the paddles.

The main disadvantage of the vertical drum was its fixed cutting height and the inherent difficulties of varying the cutting horizon to negotiate minor faults and seam variations. The drum removed a web of coal about 610 mm deep as it progressed along the face. The 'Dran Yam' machine was the best known, vertical drum, cutter-loader. It did not find popular acceptance partly because of its fixed cutting height and lack of horizon control but also because of the development of other, more versatile machines.

5.5.3 Horizontal Trepanning Drum

In the early 1950's the trepanner cutter-loader was introduced. The principal cutting element of this machine was a horizontal drum with its rotational axis parallel to the conveyor. The main body of the machine rested on the floor but with its gob side resting on an adjustable steel rail support running along the face

side of the AFC. The machine had trepanner cutting drums at each end to be capable of cutting in both directions as it moved back and forth through the face. Machine travel was obtained by an hydraulically powered sprocket which engaged in the links of 'dead' chain attached to spring loaded anchors mounted on the conveyor structure at each end of the face. An illustration of a floor mounted longwall trepanner is shown in Figure 5-8. The trepanning head attacks the buttock of a web about 610 mm deep. The trepanning head consists of an open-ended drum rotating about its axis. Two opposite sides of the drum are also open. Cutting picks are placed around the periphery of the open end so that as the drum is advanced into the solid coal buttock a circular cut is made. As the drum continues to advance, a coal core enters the drum and is broken up by picks located inside the drum. the rotation of the drum, picks up the broken coal and loads it onto the conveyor through its open sides. The drum rotates at about 80 rpm with a pick speed of about 3 m/s. this slow cutting speed and the well ventilated trepanning cutters almost eliminates the hazard of frictional ignitions at the cutting head. However, the circular trepanner cut has to be squared off and to do this the trepanner machine uses a roof cutting disc, a chain type shear jib and a chain type pre-cut jib. The disc and shear jib cuts are well ventilated but the pre-cut jib at floor level is not. A considerable number of methane ignitions occurred as a result of incendive frictional sparking in the pre-cuts of trepanners.

This was because:

- cutting was at floor level
- horizon control on floor mounted trepanners was inadequate
- the location of the jib behind the machines prevented adequate ventilation of the cut.

Some of these problems were overcome when trepan-shearers were developed. These machines were mounted on the conveyor to provide positive horizon control from hydraulic jacks on the machine underframe. The pre-cut shear jib and the roof cutting disc were replaced by a single shearer cutting drum rotating on a horizontal axis and extending from the machine at right angles to the face. This arrangement was a considerable improvement in both production and freedom from frictional sparking since both trepanner head and shearer drum were well exposed to the ventilation. Sprays were provided which liberally applied water to the cutting elements. The main objective of the sprays was to allay dust though its cooling effect was believed to help suppress frictional ignitions.

The disadvantages of the trepanner and trepan-shearer were:

- they required stables at the face ends (the trepanner had to be mechanically prepared to cut back)
- the trepan-shearer could only cut in one direction. It pulled a plough behind it to clean up loose coal and had to be flitted back through the face to start another cut
- the trepan-shearer was not well suited to weak roof since supports could not normally be moved forward under newly exposed roof until after the machine had passed on its flitting run
- the trepanner was not well suited for negotiating minor faults due more to the difficulty of horizon control than cutting ability. The trepan-shearer was better suited to cutting through minor faults.

The advantages of the trepanner and trepan-shearer were:

- their capacity to produce +50 mm size coal
- their ability to leave a coal roof where roof strata was weak
- capacity for multi-shift, non-cyclic mining.

The trepanner type machines were applied under the following conditions:

Face Gradients: Level to about 20° though, apart from power demands, there was no reason why the trepanner cutting principle could not be employed on gradients steeper than 20°.

Seam thickness: From a minimum of 0.9 m to about 1.5 m, although the trepanner drum did not exceed a diameter of about 900 mm. In the case of the trepan-shearer the maximum thickness was determined by the shearer drum diameter.

Coal Hardness: With increased motor power on coal face machinery there was little or no restriction on the hardness of coal that could be cut.

Face Length: Nominally 200 m but limited by conveyor capacity and power rather than the capacity of the cutting machine.

The mechanical features of trepanning type machines are:

Rotational speed of trepanning head:	80 rpm (approx.)
Pick speed of trepanning head:	3 m/s (approx.)
Traversing speed of machine:	0 to 5 m/s depending on coal hardners and power

Power Supply: Electric motor driving an hydraulic pump. Cutting gears driven direct from electric motor; cutting disc horizon control, lifting jacks and haulage sprocket powered from hydraulic circuit.

Motor Power: From 60 kW to 100 kW on later models.

The use of trepanners and trepan-shearers was discontinued when the UK demand for +50 mm size coal declined and they were replaced by the shearer drum machines which were more versatile in faulty ground and applicable over a much wider range of mining conditions.

5.5.4 Horizontal Drum Shearer

The shearer drum rotates about a horizontal axis that extends at right angles from a conveyor mounted machine to the face (see Figure 5-9). The cutting drums of modern shearers have the ability to be hydraulically raised and lowered. The length of the arms enables the drums to cut beyond the ends of the machine (see Figures 5-10 and 5-11). In this way the shearer can cut its own advance into the face for the next web without face end stables having to be prepared.

The development of the ranging drums has increased the cutting range of shearers up to 5 m. The development of the shearer-loader and its adaptation to such a wide variety of conditions has led to its almost universal adoption as the standard longwall cutting machine.

The disadvantages of the shearer are:

- it produces a high proportion of -50 mm coal size. This is no longer a marketing problem but it does increase coal cleaning cost and gas release at the face
- it tends to produce high levels of airborne dust
- it is associated with frictional ignitions under certain circumstances.

The advantages of the modern shearer are:

- it is a robust reliable machine
- it can be operated without the need to prepare face-end stables and is non-cyclic
- it is currently the most productive machine available
- it can cut a coal roof
- it can negotiate minor faults
- its cutting horizon can be controlled automatically.

The shearer can be applied in the following conditions:

Face Gradients: Level to 70° when operating with specially designed steep face installations.

Seam Thickness: From 0.6 m to 5 m.

Coal Hardness: Can cut all coal regardless of direction of cleat and hardness.

Shearers are the most widely used longwall power loading machines in North America and are employed on all the producing faces in the Sydney coalfield.

5.6 FRICTIONAL IGNITION HAZARD

5.6.1 Background

With the development of mechanized longwall mining the following trends emerged:

- The increasing energy delivered at the picks of more powerful machines resulted in an increased number of frictional ignitions. In Britain, during the period January 1958 to June 1965 there were 123 ignitions (an average of 16.4 per year) of which 70% were on the face and included ignitions in the cut (Bakke et al, 1967). The 1983 estimate for British mines is 10-20 frictional ignitions per year (Evans, 1983).
- The risk of an ignition is significantly reduced if the cutting zone is well ventilated.
- Shallower, or thinner cutting webs are usually better ventilated than deep cuts, particularly cuts at floor level where loose coal collects.
- Dust suppression tended to receive more attention than frictional ignitions.

- Measures to deal with dust were not always compatible with measures to deal with frictional ignitions.

5.6.2 Hazard Reduction

Some of the measures adopted were primarily aimed at dust reduction with reduction of frictional ignitions a secondary objective. These measures were generally related to picks and sprays.

Picks and pick boxes were developed which would enable the pick to deliver a 'point attack'. This was to reduce the high friction, shearing mode of cutting picks. These picks were round and 'pencil pointed'. The pick box holder allowed the pick to rotate so as to obtain even wear and permit the pick to be self sharpening. It was argued that sharp picks lost less energy to friction. Cutting drum speeds were reduced, again mainly to combat dust problems, but it was thought that slow moving picks would present less of a frictional ignition hazard. None of these measures proved to be significantly effective.

Sprays delivering increasing volumes of water to the cutting edge of the picks were developed, mainly to control dust. However, it was believed that the cooling effect of the water and the saturation of the air with moisture would help reduce friction ignitions.

Additional precautions being used on shearers include delivering water through a venturi to draw in air. The air is delivered to the back of the cut via the hollow shaft of the shearer drum to ventilate the immediate cutting zone.

5.6.3 Emerging Concepts

It is anticipated that efforts to ventilate the immediate cutting zone will continue. Larger volumes of air will no doubt be able to be both delivered to, and drawn in from, the cutting zone.

It may also be feasible to replace air by non-flammable gases such as carbon dioxide and nitrogen.

Research has been directed towards developing alternative materials for cutter picks but without encouraging results. the most significant advances being made are related to the use of low volume, ultra-high pressure water jets to replace the conventional pick for coal cutting. This technique is already proven as an alternative to drilling bits.

5.7 CONCLUSIONS

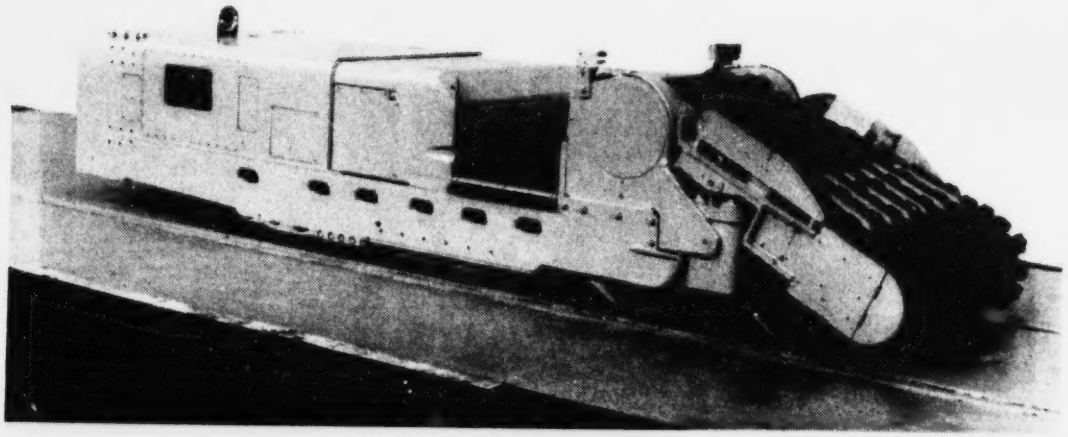
Of the cutting methods reviewed, three options appear worthy of further consideration:

- The Huwood Slicer.
- A plough employing high pressure water jets as the cutting medium.
- A modified shearer system incorporating water jet cutting.

These systems are discussed in Section 6.

FIGURE 5-1
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

THE DOSCO MINER



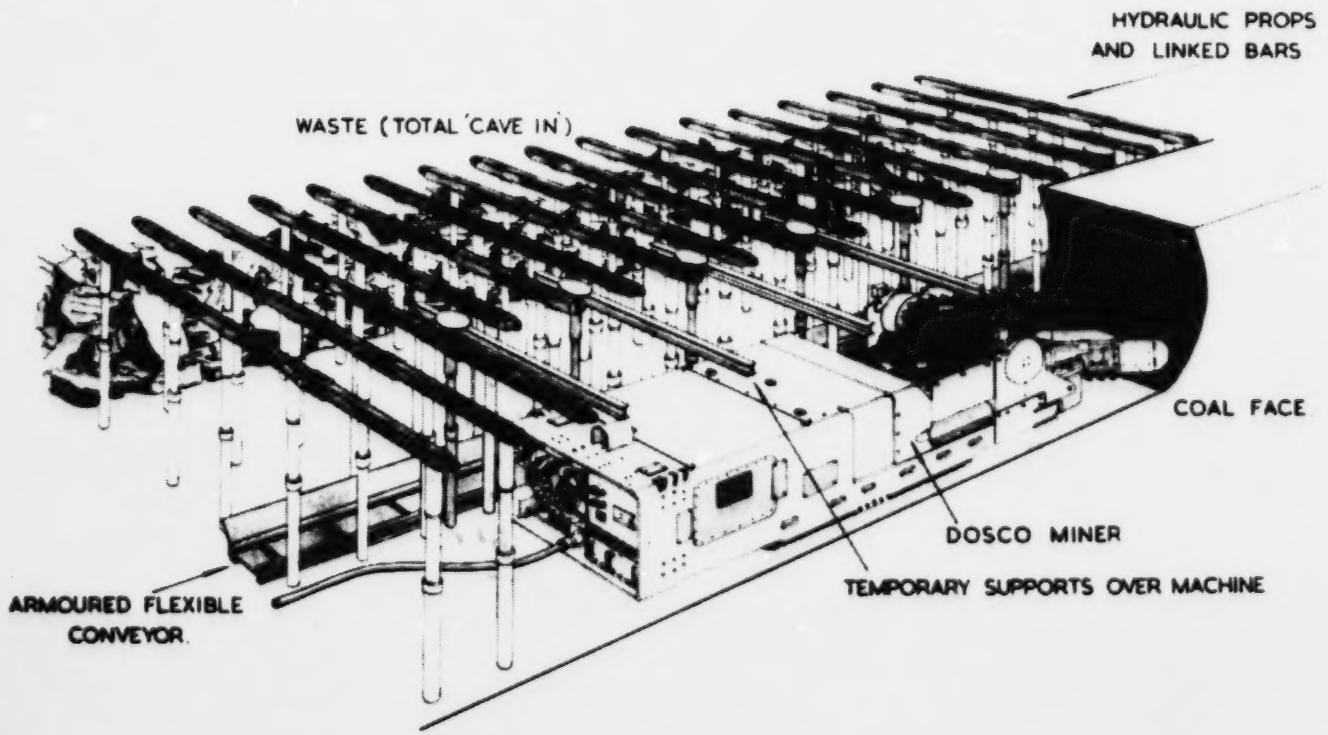
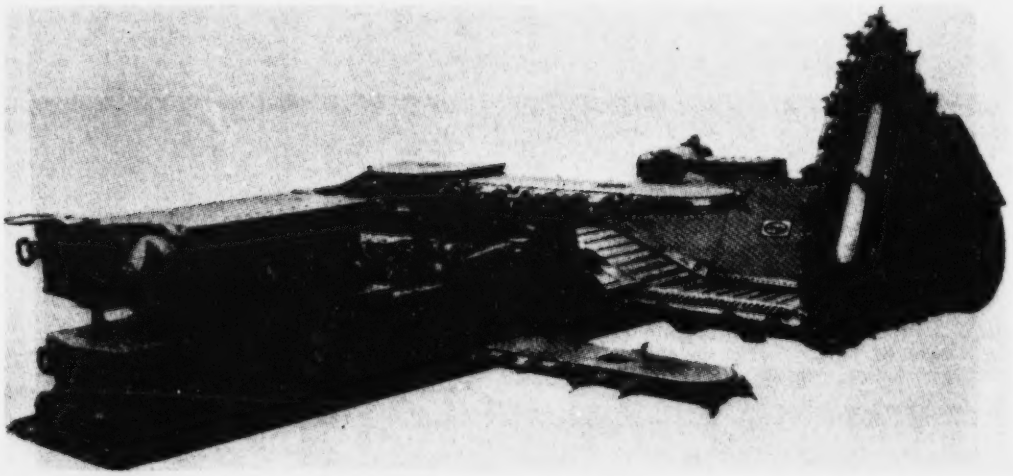


FIGURE 5-2

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

MECO-MOORE CUTTER-LOADER



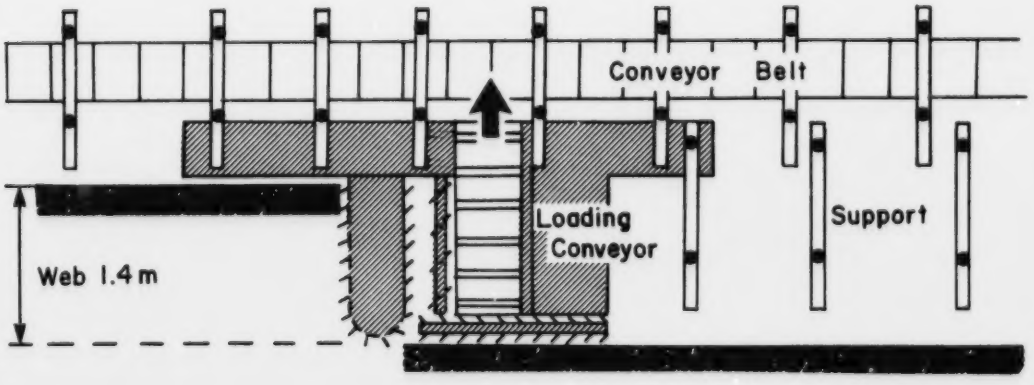


FIGURE 5-3

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

ADVANCE HEADINGS

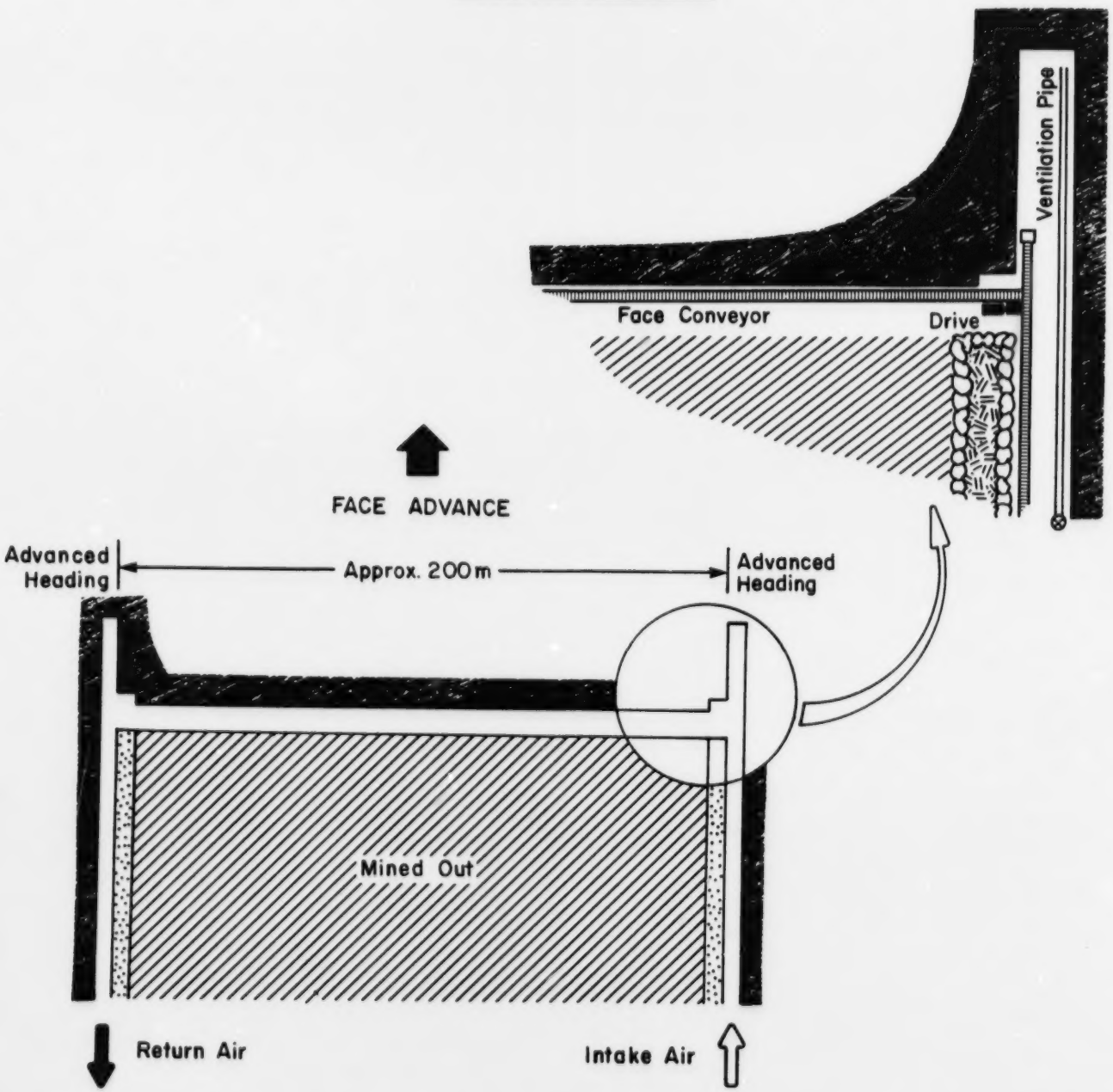


FIGURE 5-4

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

RETREAT LONGWALL

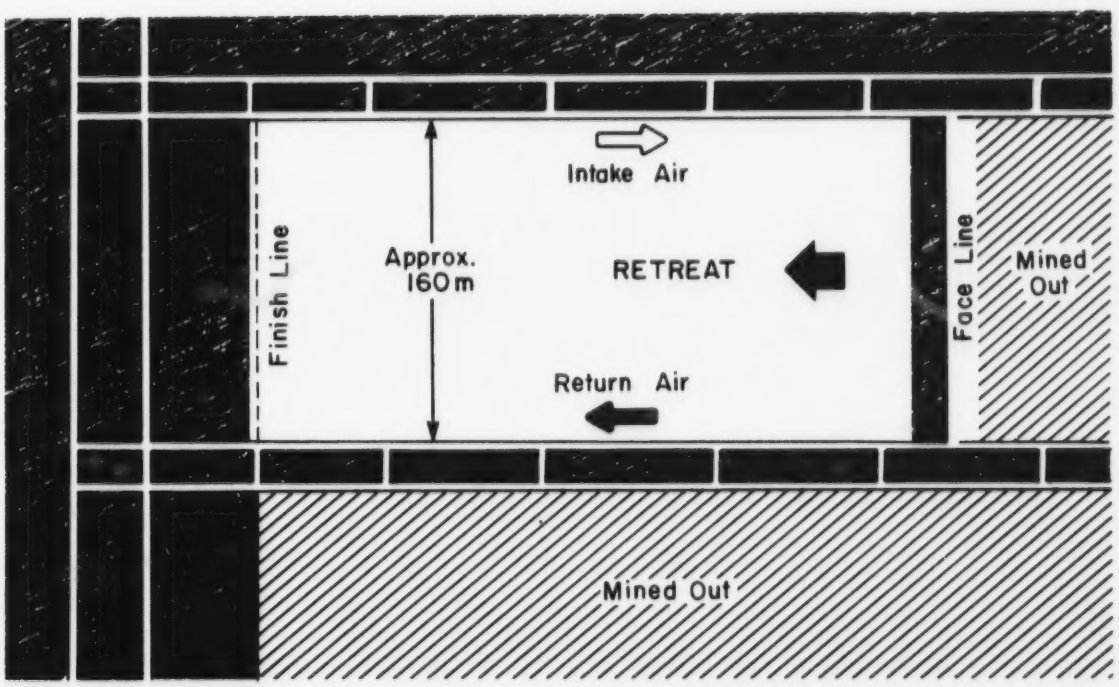
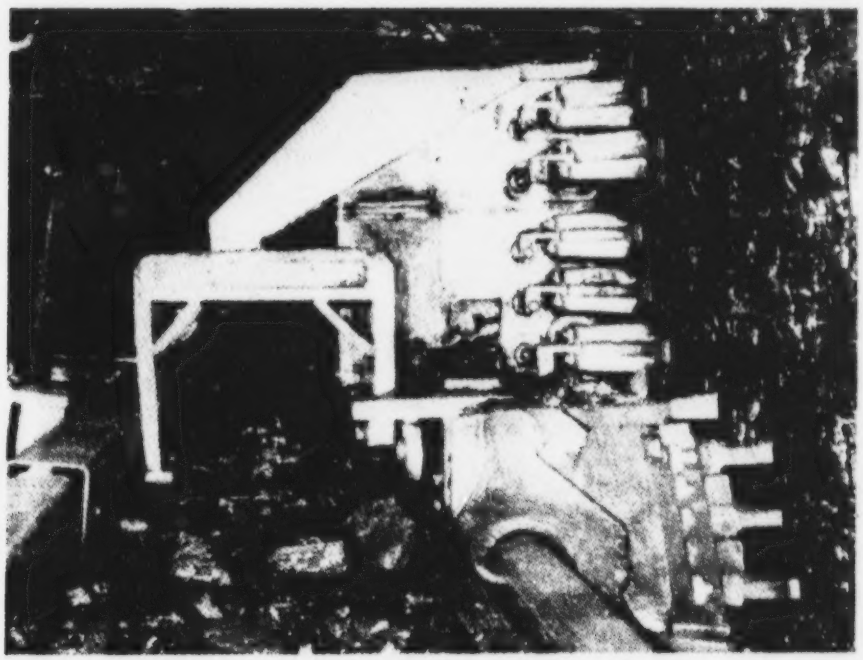


FIGURE 5-5
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

TYPICAL PLOUGH FACE LAYOUT



View of Coal Plough showing cutting teeth

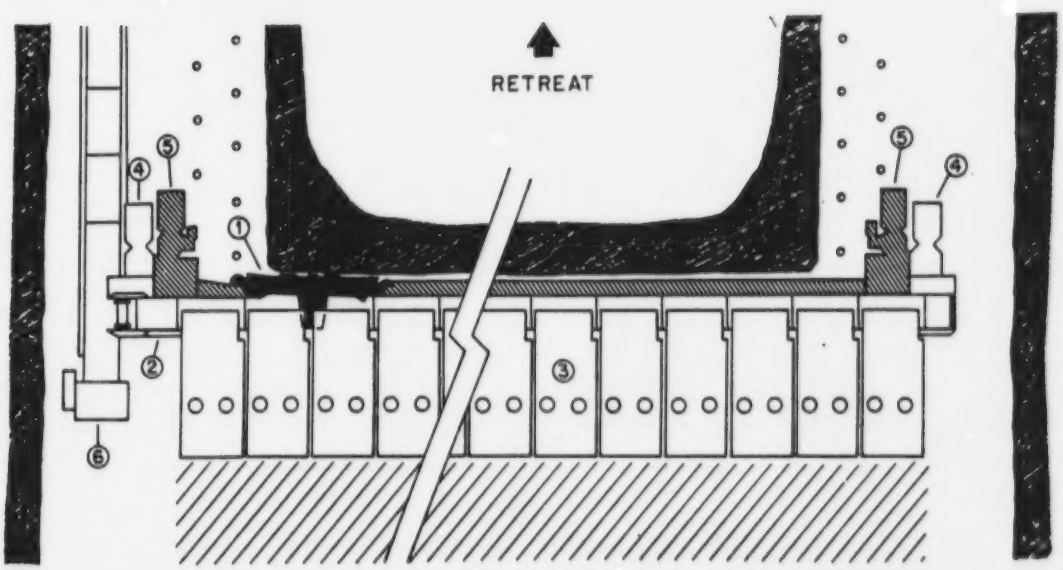
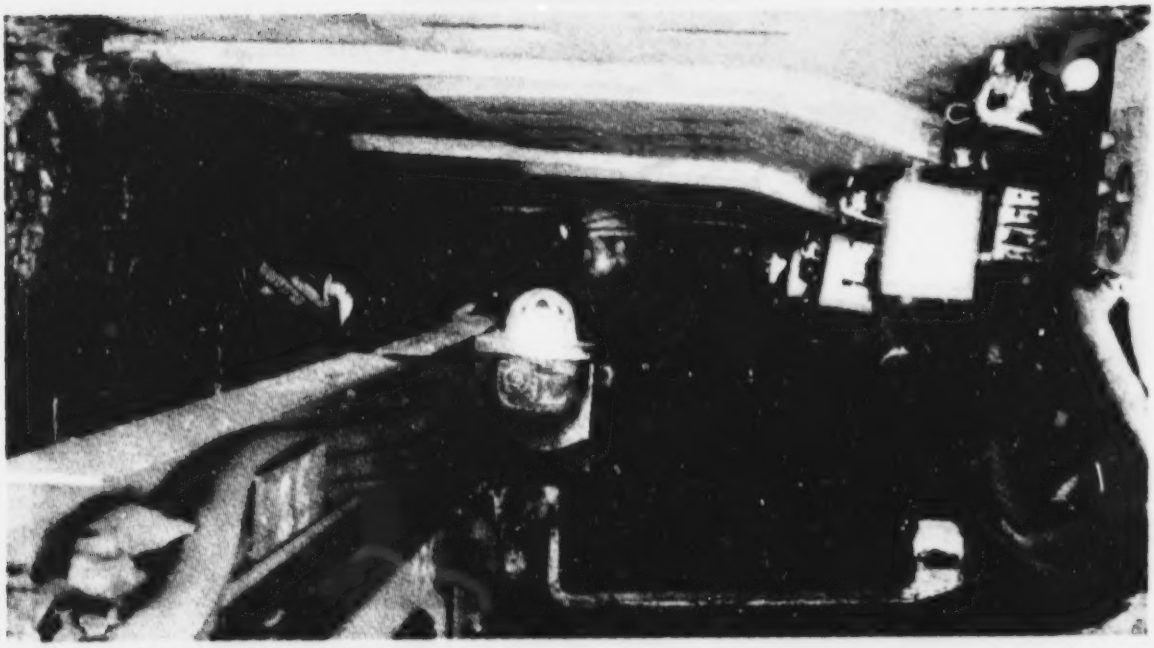


FIGURE 5-6
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

PLOUGH INSTALLATIONS



a) Stabilizer under conveyor

b) Stabilizer over conveyor

FIGURE 5-7

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

HUWOOD SLICER UNIT

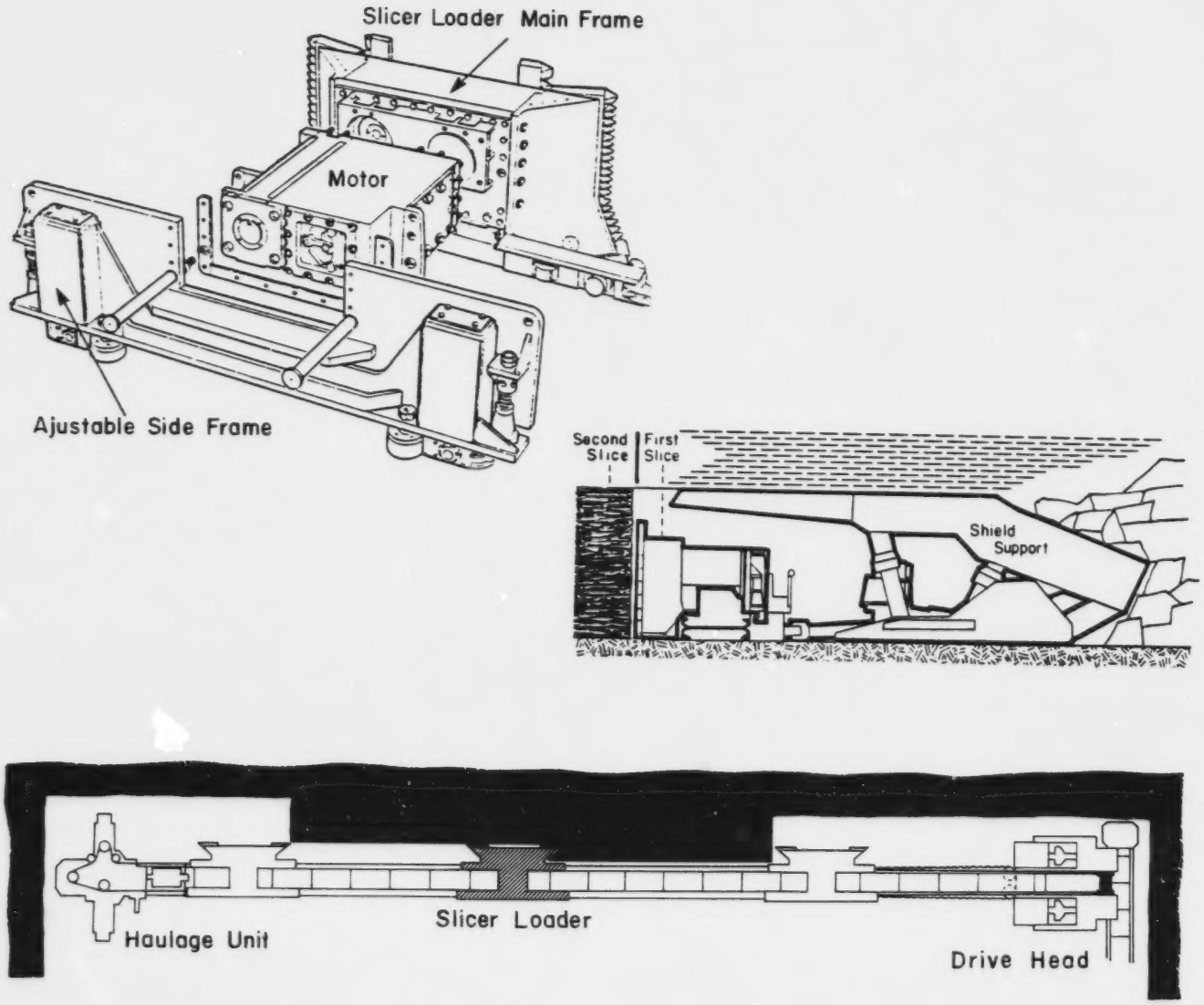
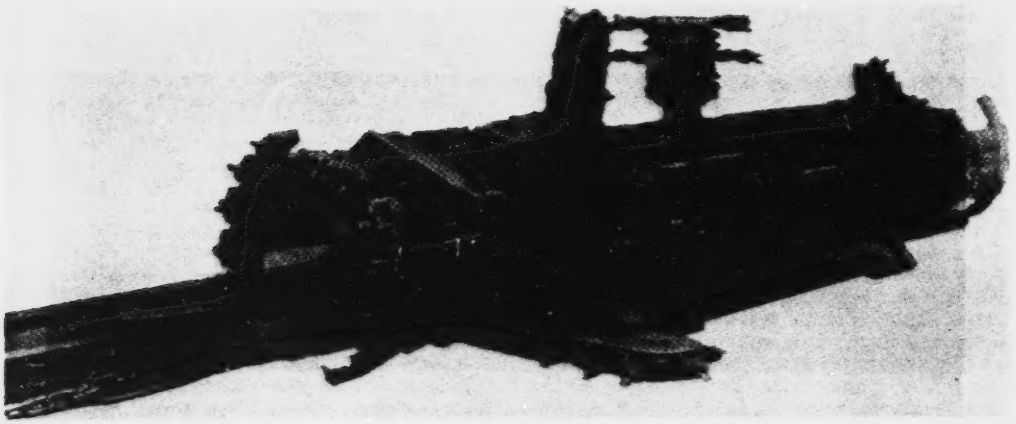


FIGURE 5-8
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

LONGWALL TREPANNER



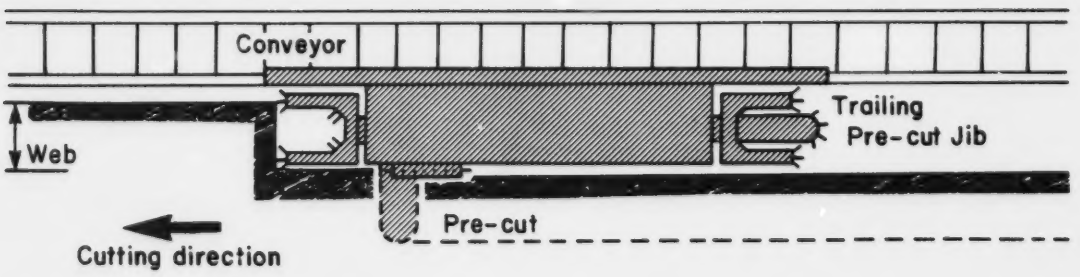


FIGURE 5-9

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

EARLY ANDERTON SHEARER-LOADER

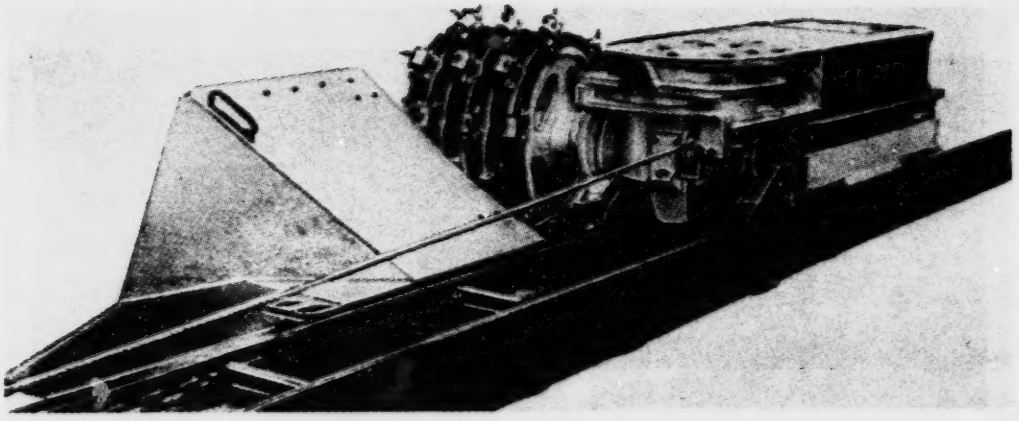


FIGURE 5-10

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SINGLE ENDED RANGING DRUM SHEARER

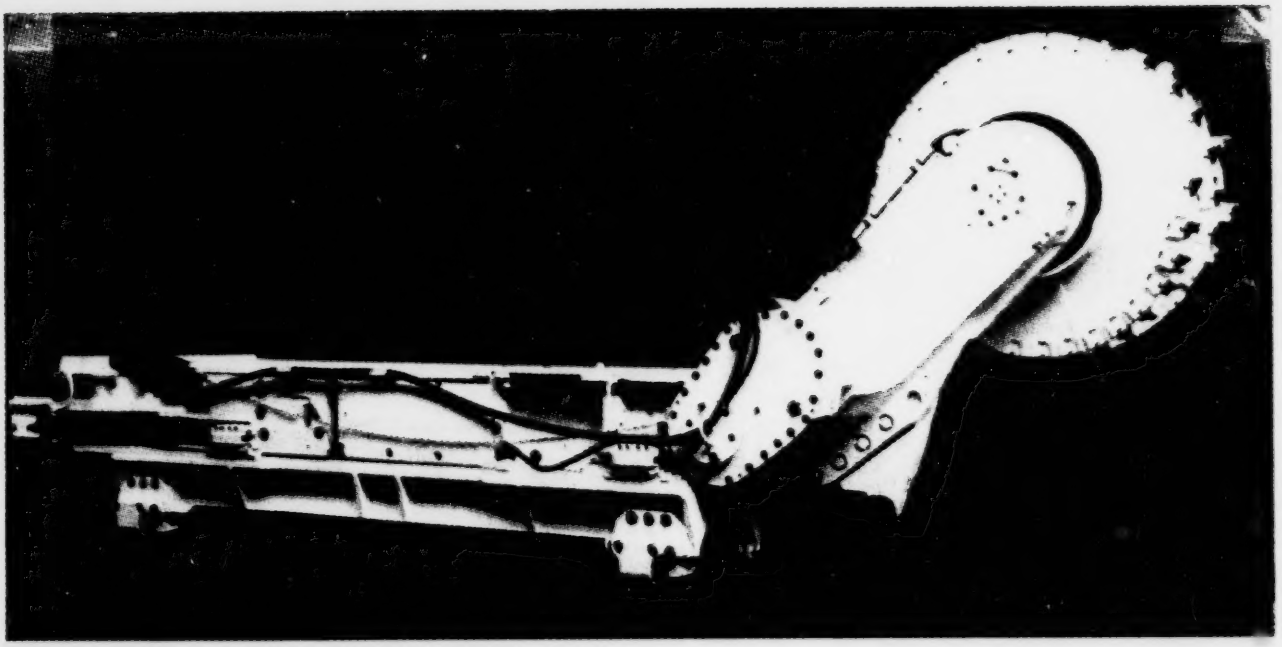
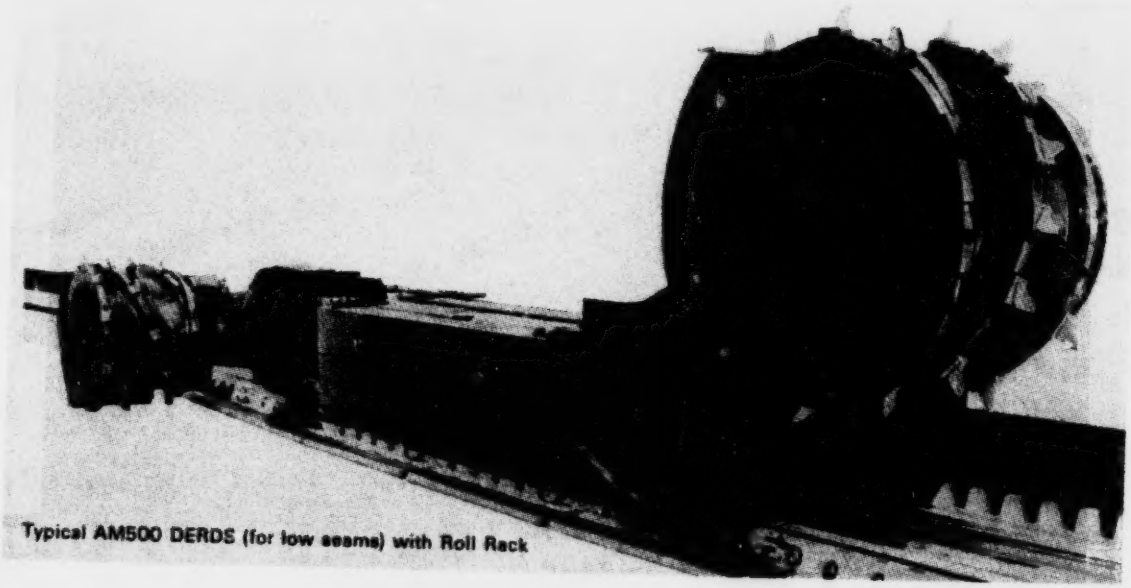


FIGURE 5-11
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

DOUBLE ENDED RANGING DRUM SHEARER



Typical AM500 DERDS (for low seams) with Roll Rack

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 6 - ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

Table of Contents

		Page
6.1	**Introduction**	6-1
6.2	**Huwood Slicer**	6-1
6.2.1	General	6-1
6.2.2	Equipment Description	6-2
6.2.3	Benefits	6-6
6.2.4	Machine Development Requirements	6-6
6.3	**Water Jet Assisted Plough Systems**	6-9
6.3.1	General	6-7
6.3.2	The Hydrominer	6-8
6.3.3	The HydroHobel	6-9
6.3.4	The Jetminer	6-10
6.3.5	Benefits	6-11
6.3.6	Machine Development Requirements	6-11
6.4	**Hybrid Shearer System**	6-13
6.4.1	General	6-13
6.4.2	Equipment Description	6-14
6.4.3	Benefits	6-15
6.4.4	Machine Development Requirements	6-16
6.5	**Performance Potential**	6-17
6.5.1	Introduction	6-17
6.5.2	Slicer	6-17
6.5.3	Water Assisted Plough	6-18
6.5.4	Hybrid Shearer	6-19
6.6	**Conclusions**	6-19

.....Cont'd

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

DSS # 03SQ.23440-3-9187

SECTION 6 - POSSIBLE ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

Table of Contents

Figures

6-1 Slicer-Loader Mounted on AFC Showing Haulage and Blade Arrangement

6-2 Slicer-Loader Mounted on AFC Showing Jacking Arrangement

6-3 Slicer-Loader - Main Components

6-4 Slicer Loader Haulage

6-5 Slicer Haulage Chain Take-up

6-6 Slicer Cleaning Plough

6-7 UMR Hydrominer Concept

6-8 GHH Jetminer Plough

6-9 GHH Jetminer Plough

6-10 Hybrid Shearer Concept

SECTION 6 - ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

6.1 INTRODUCTION

Based upon an understanding of the mechanism for initiation of frictional ignitions and on the mining environment and mining systems in the Sydney Coalfield, three candidate systems with the potential for reducing the frictional ignition hazard have been identified.

Each of the systems has the potential to achieve satisfactory production and productivity levels whilst requiring minimum change to existing roof support and face conveying systems. To obtain the maximum benefits, the systems identified should be employed in the 'retreat' mining mode.

The three candidate systems meriting further consideration are:

- Huwood Slicer
- Water Jet Assisted Plough
- Hybrid Shearer

These three systems are discussed below.

6.2 HUWOOD SLICER

6.2.1 General

Hugh Wood and Co. Ltd. (UK) commenced development of a plough type power loading machine with activated cutting elements in 1949. The machine was developed largely to overcome the difficulties of ploughing the hard coal encountered

throughout the British coalfields. Although subjected to considerable development effort (Figures 6-1 and 6-2), the machine was gradually displaced as the drum shearer developed. However, the principle of the slicer is well proven and its application successfully demonstrated.

6.2.2 Equipment Description

The description of the slicer loader is based on equipment in use in the late 1960's. The Slicer, which is mounted on an armoured face conveyor, slices and loads in both directions and travels at either 0.01, 0.09 or 0.11 m/s, taking an average slice of 250 mm. It is comprised of three main units (Figure 6-3), the power unit, mainframe and adjustable goaf frame.

A 45 kW 960 r.p.m. electric motor bridges the conveyor leaving a clearance of more than 430 mm, for the free passage of coal on the conveyor. This unit assist in rigidly bracing the two other main components of the Slicer.

The main frame, located on the face side of the conveyor, consists of two static ploughs attached to a central gearbox. Projecting in front of the ploughs are the activated combined wedge plate and pick blades which cut and wedge off a 250 mm wide strip of coal and so enable the static plough to load it onto the armoured conveyor. The base of the main frame travels on the seam floor, but the unit has guide wheels attached which fix its position in relation to the conveyor.

Originally the slicer blades described a 50 mm diameter circle at 340 r.p.m. Since wedge plates were incorporated in the design, which reduced hauler pulls, experiments were instituted with the blades describing 25 mm and 13 mm diameter circles. These have

functioned satisfactorily, removing vibration from the machine without detracting from its getting action.

Various combinations of vertical moving pick blades, and static bottom blades at floor level are available to suit different mining conditions and to control the slicing horizon. To cater for certain seams where the top coal does not readily part from the roof, extension blades can be fitted to enable the machine to slice to a maximum height of 2.0 m.

It is recommended that initially the slicer should be installed with the standard blade arrangement and that any subsequent variations be made only after an adequate trial period.

The Slicer blades are machined from a low tungsten alloy steel and in coals of medium hardness they have given three months service before being removed for re-sharpening. If hard bands in a section being worked cause excessive wear to one or more blades, these can be readily changed since the basic machine has six separate blades secured by socket-headed screws at each end of the slicer.

The use of the activated blades as a means of getting coal ensures that only large coal is wedged off the face without creating fines. This bursting of coal often takes place some two to three feet in advance of the blade tip.

The adjustable goaf frame is made up to two plates, one of which is fitted with two screw jacks and guide wheels whilst the other is bolted to the motor. These plates are held together by guide pillars which allow them to slide relative to each other in the vertical plane by operation of the screw jacks, to assist in controlling the slicing horizon. The goaf frame assembly is

supported on both horizontal and vertical guide wheels which are located in the goaf side of the conveyor. The 50 mm thick plate from which the two goaf frame plates are manufactured also afford a safe barrier between falling coal and the slicer operation.

Basic dimensions of the electric slicer are:

Height (minimum)	1070 mm
Width	1400 mm
Length	3900 mm
Weight	5.3 t

Clearance between slicer motor and conveyor for passage of coal:
435 mm (high) by 530 mm (wide).

The hauler unit (Figures 6-4 and 6-5), forms an integral part of the conveyor tail end assembly and comprises:

- Power Unit
- Gearbox
- Automtic chain Take-up.

A 19 kW 970 r.p.m. motor which driven through a traction fluid coupling. Transmission through a totally enclosed gearbox provides reductions obtained through the four stages of either 265.12 to 1, 189.83 to 1 or 153.22 to 1, giving corresponding hauler chain speeds of 0.01 m/s, 0.09 m/s or 0.11 m/s respectively. Drive to the hauler chain is obtained through a horizontal six toothed machined sprocket secured at the bottom of the last reduction shaft.

Oil lubrication to bearings and gears above the normal oil level in the gearbox is supplied through a battery of six piston pump units

operated by an eccentric cam on the 3rd reduction shaft. The gearbox is designed to give a haulage chain pull of 25.4 t.

An automatic chain take-up provides a means of taking up slack hauler chain as it leaves the hauler drive sprocket. Depending on the direction of movement of the slicer, this slack can be at either side of the driving sprocket. The slack chain so produced is taken up by one of two spring-loaded sliding sprocket assemblies housed in the chain take-up unit in which they can travel outwards at right angles to the armoured conveyor. When slicer hauling commences, the tension applied by the hauler chain overcomes the 650 kg tension of the spring and pulls the sliding sprocket towards the conveyor to a limiting stop. On the other side of the system, however, slack chain develops on leaving the driving sprocket and in this case, the movement of the opposite sliding sprocket outwards, under the influence of the springs, serves to take up this slack chain. The automatic chain take-up can deal with approximately 2 m of slack chain in the hauler chain circuit. Chain of 22 mm diameter is used.

The hauler chain is attached to one end of the slicer by means of a special connector. It then passes along the face side of the conveyor to the hauler unit after which it returns to the goaf side through cover guards attached to the coneyor. Two idler sprockets built into the underside of the first ramp pan of the conveyor guide the chain back onto the face side where it then passes along the face and is secured to the other end of the slicer.

To ensure a clean track behind the slicer and thus obtain adequate snaking of the conveyor, a simple double-end cleaning plough (Figure 6-6) is attached to the hauler chain and towed approximately 3 m behind the machine. The dimensions of this plough are 450 mm wide, 775 mm high, 1385 mm long.

6.2.3 Benefits

The advantages to be gained from application of the slicer principle to seams with frictional ignition potential are:

- The machine produces larger coal than the shearers, reducing dust make and consequently the potential for a methane/coal dust explosion. Dust suppression water requirements are also reduced.
- The cutting speed of the picks is low, greatly reducing the potential for frictional ignitions.
- The shallow depth of cut and configuration of the machine assist adequate ventilation of the cutting/loading zone.
- The shallow depth of cut and consequent reduction in unsupported roof exposed can effect an improvement in roof control in difficult mining areas.

6.2.4 Machine Development Requirements

Previous experience obtained with the machine has demonstrated the practicability and potential for its application. However, since its use has been discontinued, the machine has not been developed to meet modern standards. Areas of redesign requiring further consideration include:

- the application of chainless haulage systems
- the use of larger horse power water cooled motors
- the adaptation to modern high capacity heavy duty conveying systems and roof support systems
- adaption of the machine to allow employment on retreat mining systems
- development and design of new cutting picks
- enhanced horizon control systems
- adaptation to mining seams of varying section.

Considerable advances in conveying, roof support, haulage and electrical systems have been achieved since that date and if the

slicer design were updated to incorporate current technology, considerable improvements in performance capability could be anticipated.

6.3 WATER JET ASSISTED PLOUGH

6.3.1 General

Early investigations of the possibility of using high pressure waterjets to cut through rock and coal indicated that it might be advantageous to operate at jet pressures on the order of 10 to 15 times the compressive strength of the rock. This erroneous concept led to the development of machines capable of firing waterjets at pressures of up to 4000 MPa (600,000 psi), and was not substantially refuted until the early 1970's. At that time the USBM funded three contracts under which the ability of waterjets to mine coal would be evaluated. These three projects were with ITT Research Institute, who examined systems which would operate at 700 MPa, the Bendix Corporation, who examined systems which would operate at around 350 MPa, and the University of Missouri-Rolla (UMR), who had proposed cutting the coal at 70 MPa. For all three systems flow rates were set which would not exceed the volumes used on existing machines (in the order of 180 L/min). The results of this work was such that two years consequent to the initiation of the contracts only the UMR study was continued, since this had demonstrated the clear practicality of working coal with commercially available equipment capable of supplying the water at the required volumes and pressures.

6.3.2 The Hydrominer

The UMR machine known as the Hydrominer was developed from experimental results through an initial prototype to a second generation machine which was constructed in the late '70's. The concept behind the device can be seen by reference to the attached artists impression of the device (Figure 6-7), prior to the original construction. Waterjets are set to oscillate along the vertical face of the plough blade, each covering a path of approximately 75 cm. Concurrently, similar arms are set to cut horizontal slot at the bottom of the web and, where necessary, at the top of the web, to leave roof coal. By use of a dual orifice design for the jets the waterjet action cuts a slot 5 cm wide in the coal face, allowing the leading edge of the plough to enter the slot and then wedge the coal from the solid over onto the adjacent conveyor. By an optimal choice of nozzle design it is possible to tailor the depth of this slot ahead of the plough, in turn controlling the breaking force, and the size of the product created. The jet angle, and the pressure of 70 MPa force the water into the web, and along potential fracture planes so that as the block falls over onto the conveyor it will break into smaller handleable size pieces, while all dust has prevciously been wetted, and never gets the chance to become airborne. Where the jets cut a slot around 60 cm deep ahead of the plough, the force required to break the coal from the face becomes insignificant relative to the loading force required to move the coal, and the machine is, therefore, comparatively insensitive, in terms of cutting and haulage forces, to the width of web which it cuts. This was demonstrated by the first generation UMR machine which increased the depth of web from 0.5 m to 1.0 m without any significant change in the haulage force required. Because the only parts moving at any appreciable speed are the feed pipes to the nozzles, and they are buried within the machine so that only

the cutting jets exit from the head, there is no source for any ignition of gases.

Following observation and discussion of this program three German companies became interested in this technology. One, Eickhoff, began their own program to develop the waterjet assisted shearer and the other two, Westfalia Lunen (Gewerkschaft Eisenhuette Westfalia Lunen) and GHH (Gutehoffnungshuette Sterkrade, one of the M.A.N. companies), working in cooperation with Bergbau-Forschung GmbH, the German research organization, began work on two different variations of the waterjet assisted plough.

6.3.3 The HydroHobel

The Westfalia machine known as the HydroHobel was tested in both surface and underground applications. Single jets were directed forward at an angle of 15° to the coalface, cutting a slot in line with the face. Sixteen nozzles were fitted to the machine at diameters ranging from 0.8 mm to 1.0 mm, for a combined flow of 180 L/min at a pressure of 75 MPa. The jets were aimed to act at the same point as the picks of the plough and did not oscillate, but rather were fixed on the body of the machine. It was found, from the underground trials, that the addition of the jets allowed an increase in the cutting rate of the machine from 4.45 m^2/min to 5.45 m^2/min.

Because of the increased power requirement to operate the nozzles, (some 265 kW) this increase was not felt to be adequate to justify further work on this design, given the greater improvement in performance shown by the GHH machine and at present further development of this design is not anticipated.

6.3.4 The Jetminer

The GHH machine known as the Jetminer (Figure 6-8 and 6-9), is similar in concept to the UMR machine, although there are some significant differences. It comprises a central section with 215 kW motor, and a high pressure pump which provides water quantities and pressures similar to those used in the UMR trials. Each end of the machine includes an articulated head incorporating oscillating single jets in the vertical plane only. Wedges are located at the end of the nozzle stroke which is approximately 25 cm, and serve to break the coal out from the face. The cutting head has no horizontal cutting jets, but relies on picks set back on the head to break the cantilever. This means that the coal must be broken from the face by the machine while it is still under vertical stress, and this has proven to be a problem with the machine.

Preliminary underground tests of the equipment indicated that, even with the single 2 mm diameter nozzle, that there was a drop-off in performance when the jet pressure fell below 60 MPa, but that above that pressure the machine could achieve cutting rates of 9.6 m^2/min. This translated, in the seam in question, to cutting speeds of up to 24 m/min with a 50 cm cut on the 1.6 m to 1.7 m high face. By reducing the diameter of the upper nozzles, the flow rate, horsepower requirements and raw coal moisture content could all be reduced, without change in machine performance.

The prototype machine worked for several months, has been withdrawn for modification, and is currently waiting to return to the Loberg colliery where it will be installed on a seam 1.40 m high, on a face 260 m long, on a level gradient, where the roof and the floor are sandstone and the coal is judged 'difficult to plough'.

6.3.5 Benefits

The application of the water jet plough provides the following benefits in seams with frictional ignition potential:

- The machine produces larger coal and less dust than shearers with reduced potential for methane/coal dust explosion.
- There are no rotating picks.
- The machine cuts a narrow web and facilitates adequate ventilation of the cutting/loading zone.
- The cutting jets provide a continuous flow of water into the cutting zone.

6.3.6 Machine Development Requirements

It is considered that the GHH machine is the most promising of the currently developed water jet ploughs but will need to be modified through the following stages for most effective performance to be achieved:

- Redesign the machine using modern smaller pumps, and through the use of dual orifice nozzles and proportional diameters use less water, and reduce the required horsepower levels below 150 kW.
- Improve the flow path geometry and nozzle design, along the lines suggested by UMR personnel. The improved designs allow cutting at up to 2000 nozzle diameters, rather than the 200 diameters normally achieved. Since there is a disadvantage in cutting too far ahead of the plough body, the coal comes out in too large a size and is not properly infused to inhibit dust make, this will mean that smaller jet diameters, and thus less water and power will be required.
- Redesign the head to allow mining more than 40 cm on a pass.

- Redesign the head to achieve a horizontal cut at the floor - as well as the breaking the coal column and making loading of the coal much easier, this will give a much more positive control to the horizon cut by the machine. this is especially true since the horizon will be created before the machine reaches it. Cutting at the roof level should also be considered, particularly where a positive roof line is required with poor conditions.

- Redesign the machine to fit within a smaller envelope than its current 8.56 m length.

- Consider adopting the use of dual orifice nozzles. The increased cutting ability because of the wider slot achieved in the coal, the consequent reduction in loading on the plough head and the reduction in dust make through increased coal infusion hold considerable possibility.

- Make provision, in the design, for cutting in seams of greater thickness. This may be achieved by increasing the oscillation range of the upper cutting jets, which, at the same diameter, tend to cut further than the lower jets. By a suitable redesign this will allow a greater flexibility in coping with variation in the seam extraction height and, through the development of a ranging feature it will allow elimination of stable holes (stalls). the water jet cutting machines operate with much smaller cutting forces on the machine and this will allow a machine redesign to produce a much smaller machine capable of achieving the same result as current equipment.

- Make provision for a better loading mechanism to move the larger coal produced onto the conveyor. This can be achieved if the head is redesigned to cut out and remove the top section of the coal before the lower section. The large force required to lift and move the coal laterally at the same time, if the bottom coal is mined first, is then no longer required.

- Provide a solid cutting surface along the leading edge of the machine, rather than the segmented three wedges currently used. This design, by Professor Summers, allows the machine to cope successfully with dirt bands, whatever their position on the face.

- Improve the steering system by the removal of the chain haulage guides, so that the conveyor pans will ride on the floor (Figure 6-8). If haulage chains are still used, some

design lessons may be incorporated from the new Gleitschwarthobel (GS plough), from Westfalia.

- Replace the haulage chains by a rack-a-track self-propelled system, using a conventional type of power pack.

- Make provision for a breaker on the upstream side of the machine to break up the increasingly large amount of blocky coal produced. While some of this extra-large coal can be reduced by change in nozzle size and geometry, this provision, similar to that frequently fitted to the tailgate end of shearers, may be required to ensure adequate size range of the product.

- Develop safety procedures to minimise the hazard of injury by high pressure water jets and to minimize the adverse effects of the machines' noise output.

6.4 HYBRID SHEARER SYSTEM

6.4.1 General

The frictional ignition hazard is significantly reduced when shearer drums are maintained completely within the coal seam. A shearer, modified to achieve this would require the least change to existing equipment and systems, and could be a viable alternative facecutting system.

Modification would require careful selection of the appropriate drum size to ensure that overlying or underlying strata were not cut, taking into account likely variations in seam thickness and roof support minimum height. The shearer drum would be arranged to extract the middle section of the seam and the overhanging and underlying coal would be extracted by high pressure hydraulic jet systems.

Such a hybrid machine would retain the major advantages of the drum shearer with a much reduced frictional ignition hazard.

6.4.2 Equipment Description

The concept of the hybrid shearer is that of a double ended machine with either fixed or ranging arms with drums sized so that they remain within the coal section. The top and bottom coal, not cut by the drums, will be broken out by high pressure water jets.

The hybrid shearer will use the high productivity shearing systems to extract the main part of the seam and use high pressure water jet technology to cut the roof and floor. By this means the drum is kept away from the most hazardous areas from a frictional ignition viewpoint - the roof and the floor - and cutting in these locations is carried out by water only.

Unlike the GHH water jet plough and the slicer, the hybrid shearer is at an early stage of evolution and has not yet been taken to the demonstration or operational stage. However, the concept requires modification to an existing machine, rather than the construction of a completely new type of machine. The development work that will be required to bring a hybrid shearer up to a demonstration level is relatively limited and consists essentially of the adaption of existing water cutting technology and appropriate loading equipment for mounting on an already proven double-ended shearer.

The machine (Figure 5-10) would incorporate high pressure, low volume pumps into the shearer unit either mounted on the machine or incorporated as an additional section within the shearer assembly, delivering water to jets mounted in

fixed bottom cutter assemblies at each end of the machine and vertically adjustable top cutting assemblies for cutting the roof.

Extensive work has already been carried out in connection with water jet assisted ploughing and has established the pressures and volumes of water appropriate for coal cutting. Recently, shearer mounted pumps designed to provide water for jet assisted cutting on shearer drums have become commercially available. Similar pumps could be used to feed the water jet cutting heads of the hybred shearer. An example is the Pitcraft Summit high pressure pump which is supplied with low pressure water from the normal dust suppression and motor cooling supply. Flows of up to 1.5 L/s at a pressure of 200 bar are currently available. Alternative pumps are being developed capable of supplying 1.25 L/s at pressures up to 680 bar.

For the Sydney Coalfield application, with a total extraction height of 1.7 m to 2 m, the hybrid shearer would be fitted with drums approximately 1.25 m in diameter. The remaining .55 m to .75 m of total top and bottom coal would be cut by the water jet assemblies. The thickness of roof and floor coal would be determined after consideration of site specific conditions including the amount of clearance required under the shearer underframe, the likelihood of roof rolls, the floor coal, loading performance and other related factors, some of which may have to be evaluated during a trial installation.

6.4.3 Benefits

The benefits from the adoption of an alternative face cutting system based on the hybrid shearer include:

- Minimum change to the existing systems and equipment.

- The most hazardous part of the cut - the top and bottom - are handled with water instead of revolving picks.
- The proven shearer drum principle is used to mine the bulk of the coal.
- Relatively little machine development is required compared with other alternative face cutting system development.
- The vertically adjustable roof cutting elements provides flexibility in cutting height to negotiate strata abnormalities or to increase the thickness of roof coal for strata control purposes.
- The major part of the face cutting system is already in commercial manufacture and the special equipment to be procured is limited to water jet roof and floor cutting units.
- A trial could be conducted with least risk since only the roof and floor cutters are experimental and in the event of technical problems the equipment could be converted back to conventional shearing.

The modification of the double-ended shearer to keep the cutting drums away from the roof and floor and to mine the remaining coal with water jets offers considerable potential for the reduction of frictional ignition hazard in the Sydney Coalfield.

6.4.4 Machine Development Requirements

In order to develop the hybrid shearer to a demonstration level, development work is required in the following areas:

- Establish the pressures and flows required for roof and floor cutters to perform effectively in the seams in the Sydney Coalfield.
- Design and develop to be compatible with commercially available double ended shearers:
  - vertically adjustable roof cutting elements
  - floor cutting and loading elements

- high pressure water pump units to be integrated into shearer assembly.

- Develop safety procedures to minimize hazard from water jets and noise.

6.5 PERFORMANCE POTENTIAL

6.5.1 Introduction

The performance requirements for a competitive alternative face cutting system has been discussed in Section 5. The basic requirements are a shift output potential of 1500 t and a face productivity potential of 40 t/manshift.

6.5.2 Slicer

Slicers have been out of operation since the earlier 1970's and, consequently, up-to-date performance figures are not available. It should be noted, however, that where slicers were employed in favourable conditions they achieved results comparable with contemporary shearers. For example, in the early 1960's shearers in one UK mine averaged 500 t/shift and a face OMS of about 13 t/manshift, which was well in excess of average shearer performance at that time.

In estimating the performance of a modern slicer in the Sydney Coalfield conditions it is reasonable to assume that a machine engineered to current standards will have similar reliability to that of a DERDS.

Based upon a 250 m retreat face, extracting a height of 2 m, to achieve a shift output of 1500 t, with an effective depth of slice of 350 mm, then the machine must pass through the face 6

times per shift. The maximum cutting speed of the last generation of slicers was 7 m/min. At this speed six passes would require about 3-1/2 hours effective cutting per shift. It is reasonable to assume that higher cutting speeds will be achieved by a modern machine loading onto a high capacity AFC and that more than 2-1/2 hours cutting per shift will be attainable.

Productivity from the slicer is projected to be comparable with that from a shearer and in the retreat configuration recommended for any future slicer trial in the Sydney Coalfield, face manpower levels are not likely to be significantly different from those of shearer installations than those at Prince. Face productivities in excess of 40 t/manshift can, therefore, be projected.

Clearly, at the present time production and productivity forecasts can only be viewed as estimates and quantative performance statistics will only be obtained following a trial.

6.5.3 Water Assisted Plough

The most promising water assisted plough is the GHH Jetminer.

The cutting performance quoted in tests completed to date ranges up to 24 m/min, in a seam 1.6 m high with a 50 cm web, to produce approximately 25 t/min, higher than most shearers under similar conditions. Given that a ploughing action frequently makes mining of thicker seams possible without additional horsepower, it can be anticipated that in the 2 m to 2.5 m seams of Cape Breton, that it is likely that performances substantially better than that of the shearers will be demonstrated. Coal size produced will be coarser, making subsequent cleaning of the coal less expensive.

6.5.4 Hybrid Shearer

The hybrid shearer performance is estimated to be similar to the achieved by conventional DERDS. Provided satisfactory designs for roof and floor elements are achieved, there is no reason to project any loss of cutting speed, nor increase in manpower requirement. Thus hybrid shearer performance is projected to be sim,ilar to that already achieved by DERDS which have shown themselves to be capable of shift tonnages in excess of 1500 t and productivity in excess of 40 t/manshift.

6.6 CONCLUSIONS

It is believed that following modification to upgrade the slicer and hydraulic plough to ensure their mechanical integrity and equipping a standard configuration ranging arm shearer with suitably arranged jet cutting system, each of the systems has the potential to achieve the necessary production capability and productivity levels to compete with established longwall facecutting systems.

FIGURE 6-1

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SLICER-LOADER MOUNTED ON AFC SHOWING HAULAGE AND BLADE ARRANGEMENT

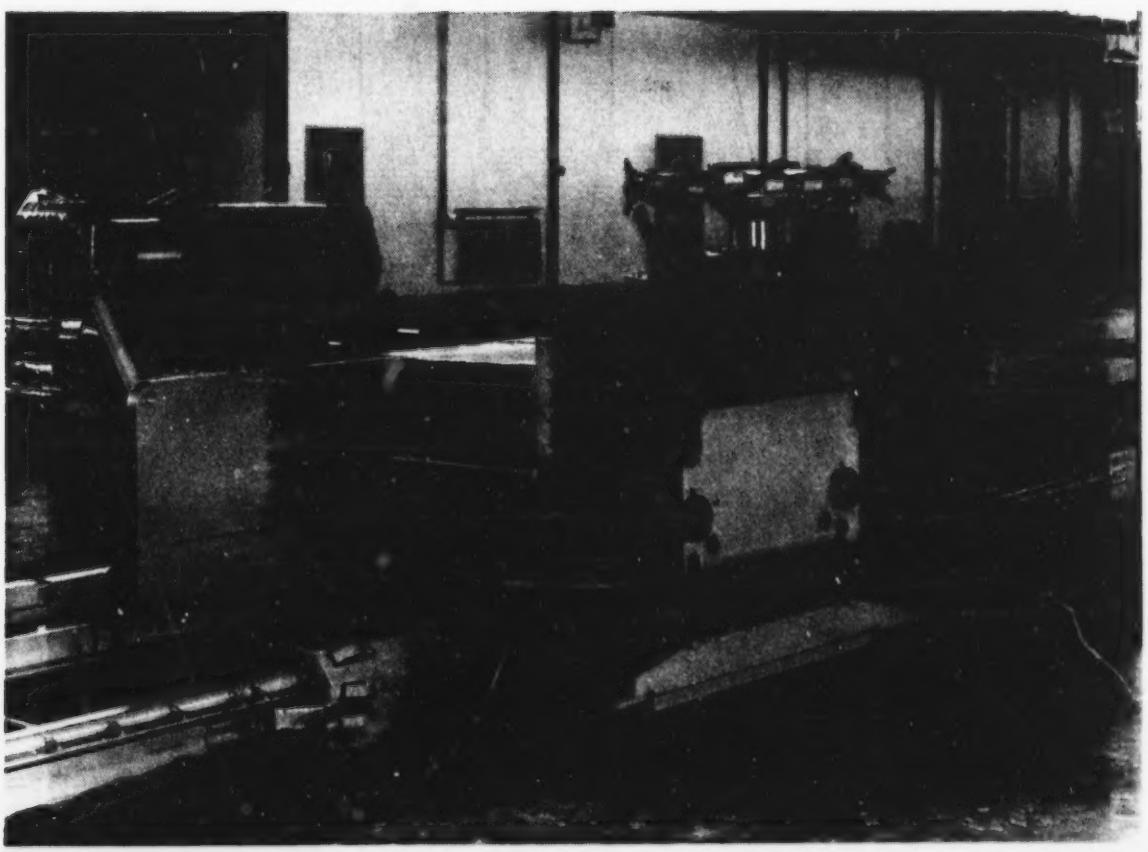


FIGURE 6-2

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

SLICER-LOADER MOUNTED ON AFC SHOWING JACKING ARRANGEMENT

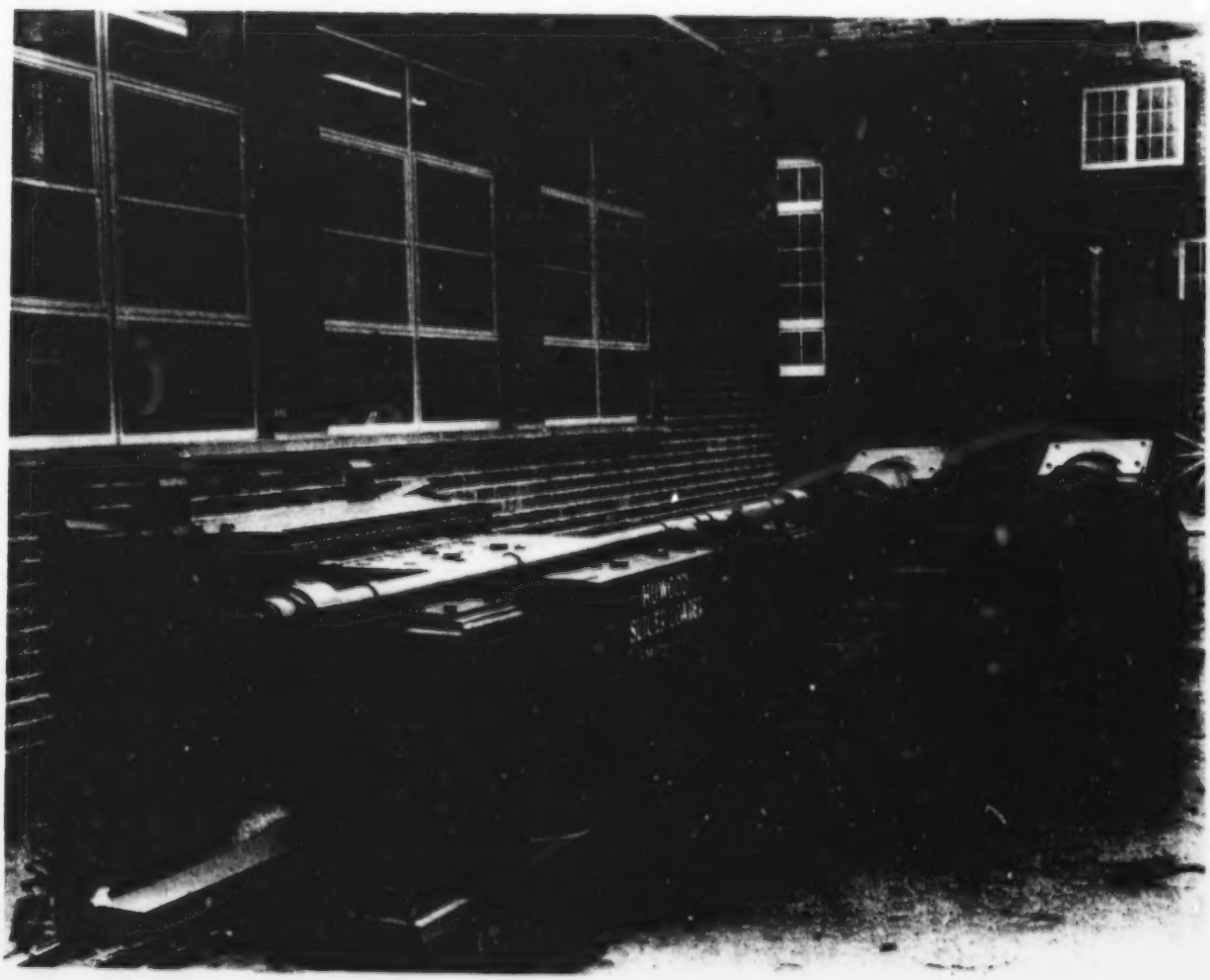


FIGURE 6-3

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS

FOR THE SYDNEY COALFIELD

SLICER-LOADER - MAIN COMPONENTS

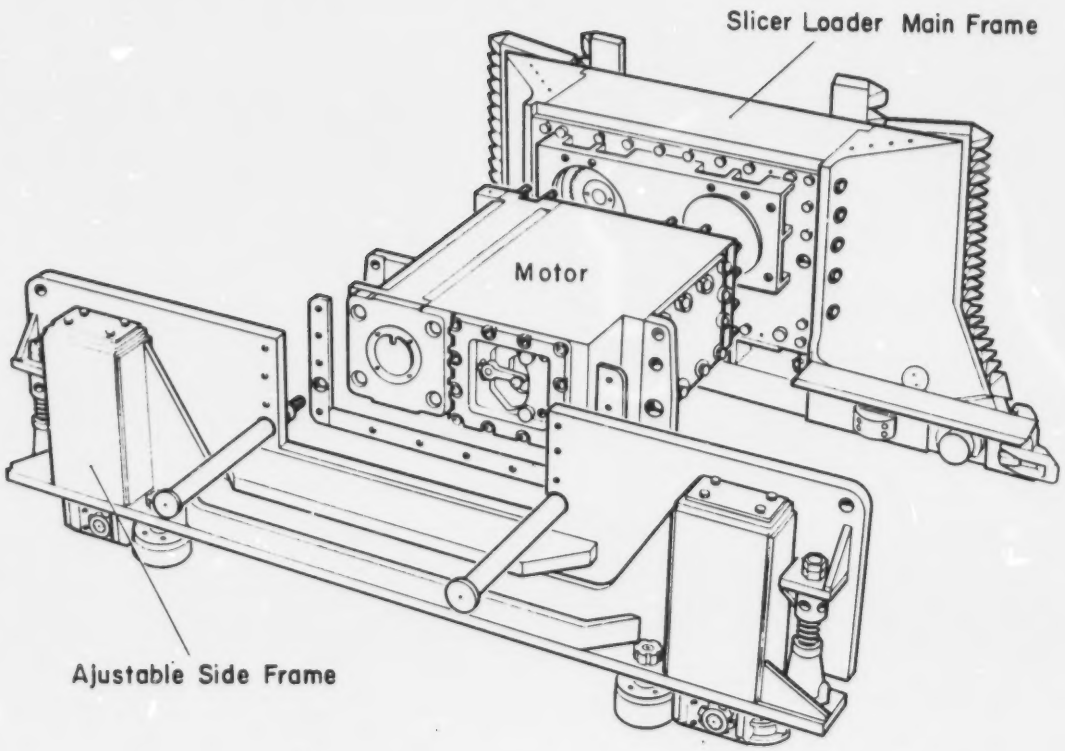


FIGURE 6-4

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SLICER LOADER HAULAGE

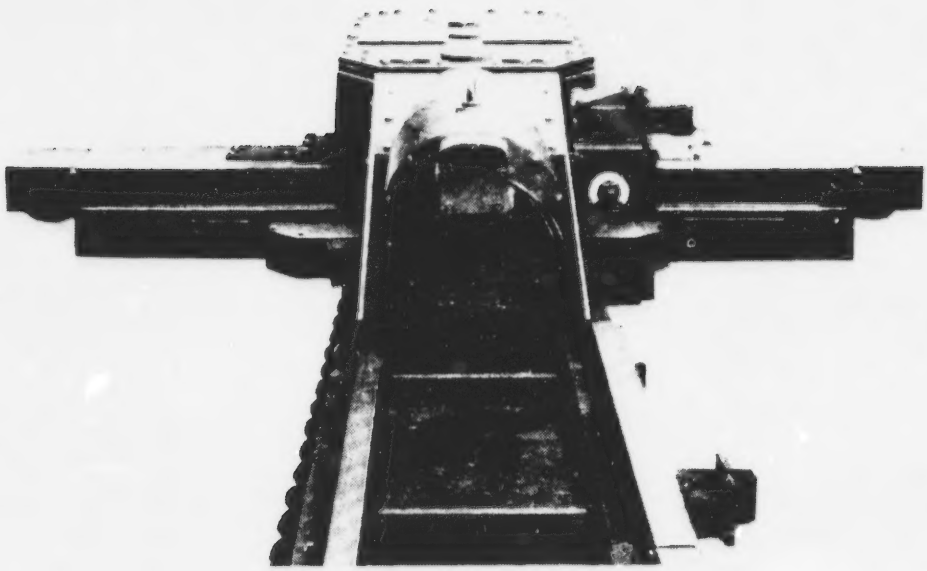


FIGURE 6-5

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SLICER HAULAGE CHAIN TAKE-UP

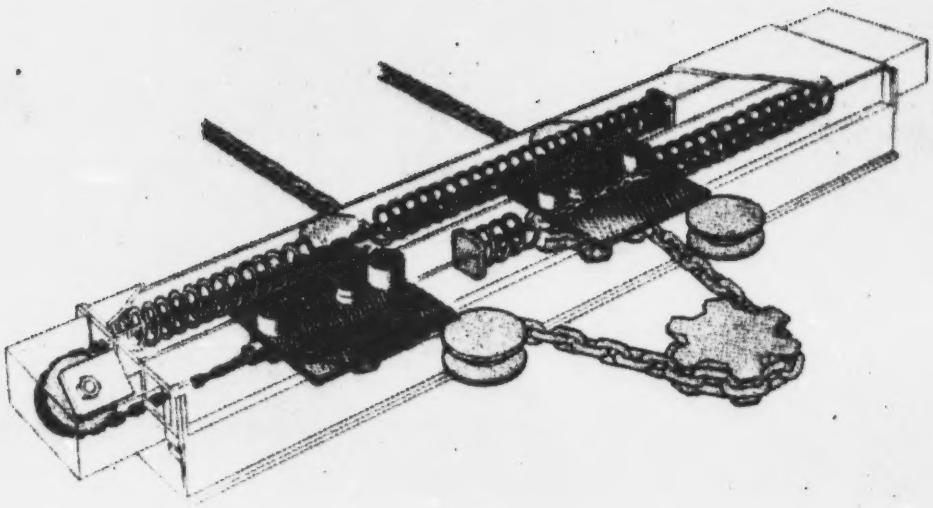


FIGURE 6-6

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD

SLICER CLEANING PLOUGH

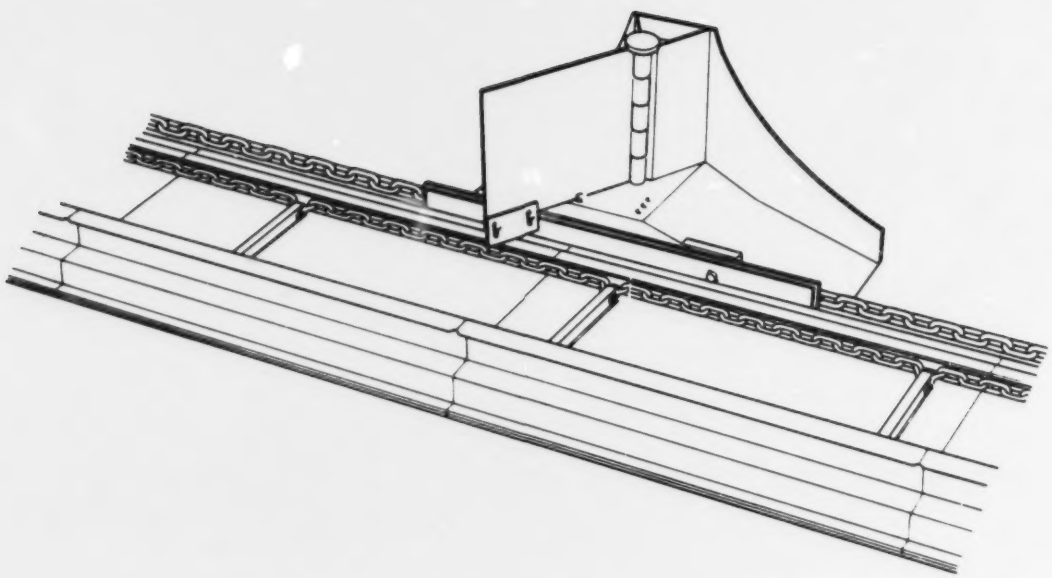


FIGURE 6-7
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

UMR HYDROMINER CONCEPT

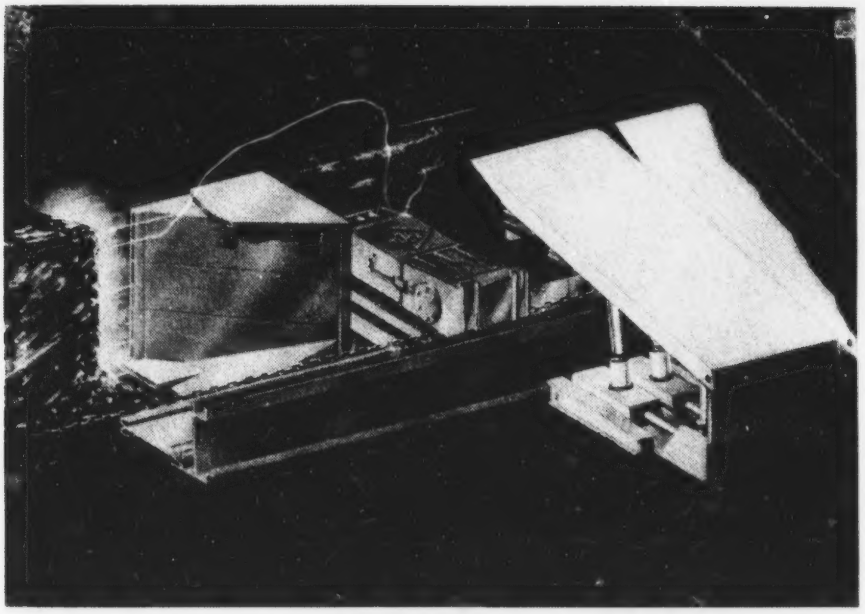


FIGURE 6-8
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

GHH JETMINER PLOUGH

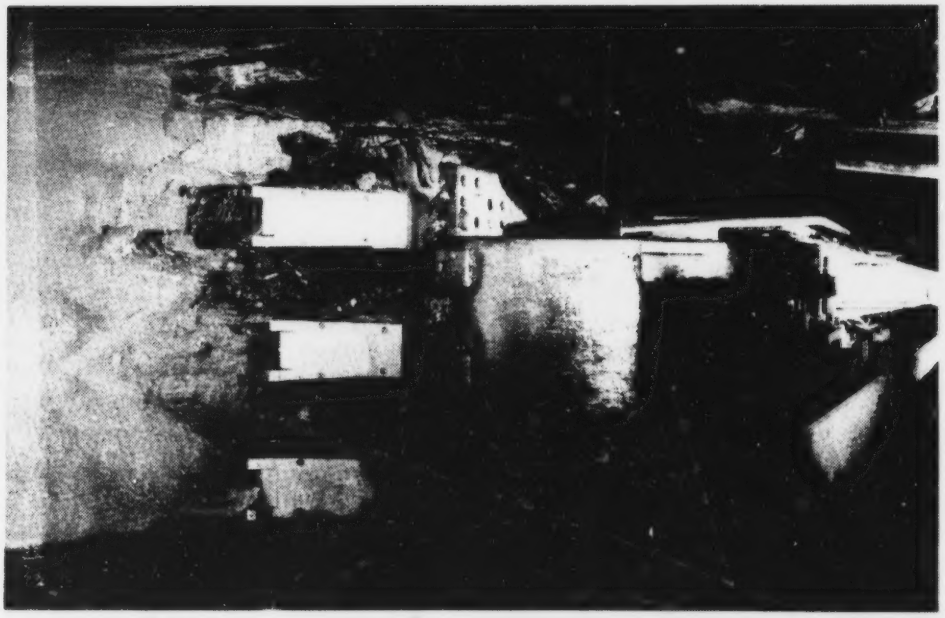
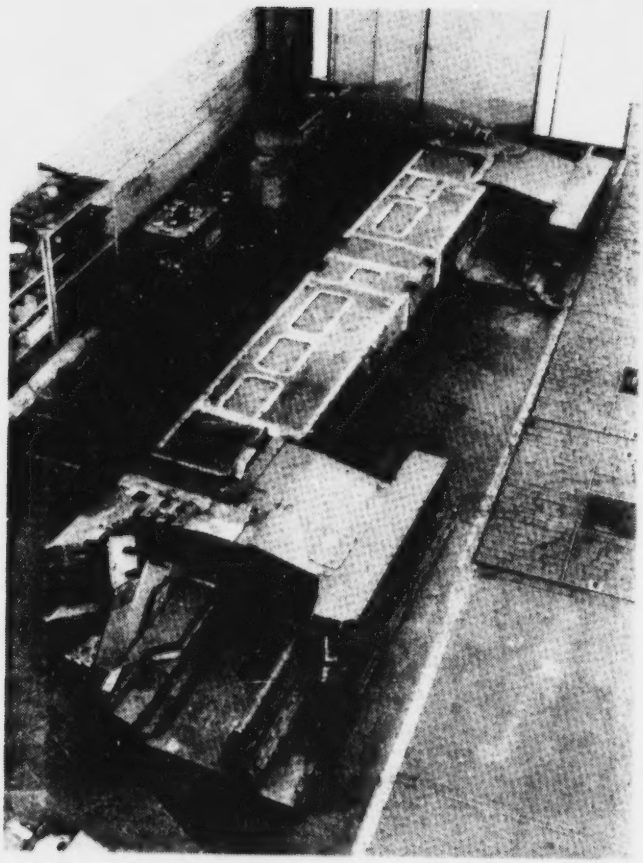


FIGURE 6-9
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

GHH JETMINER PLOUGH



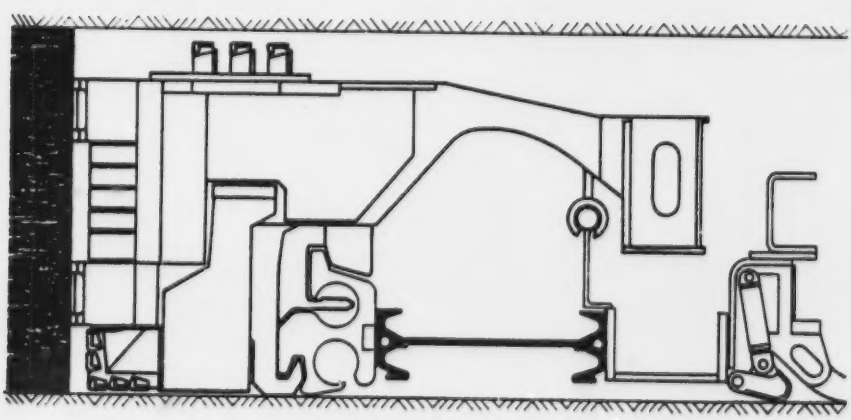
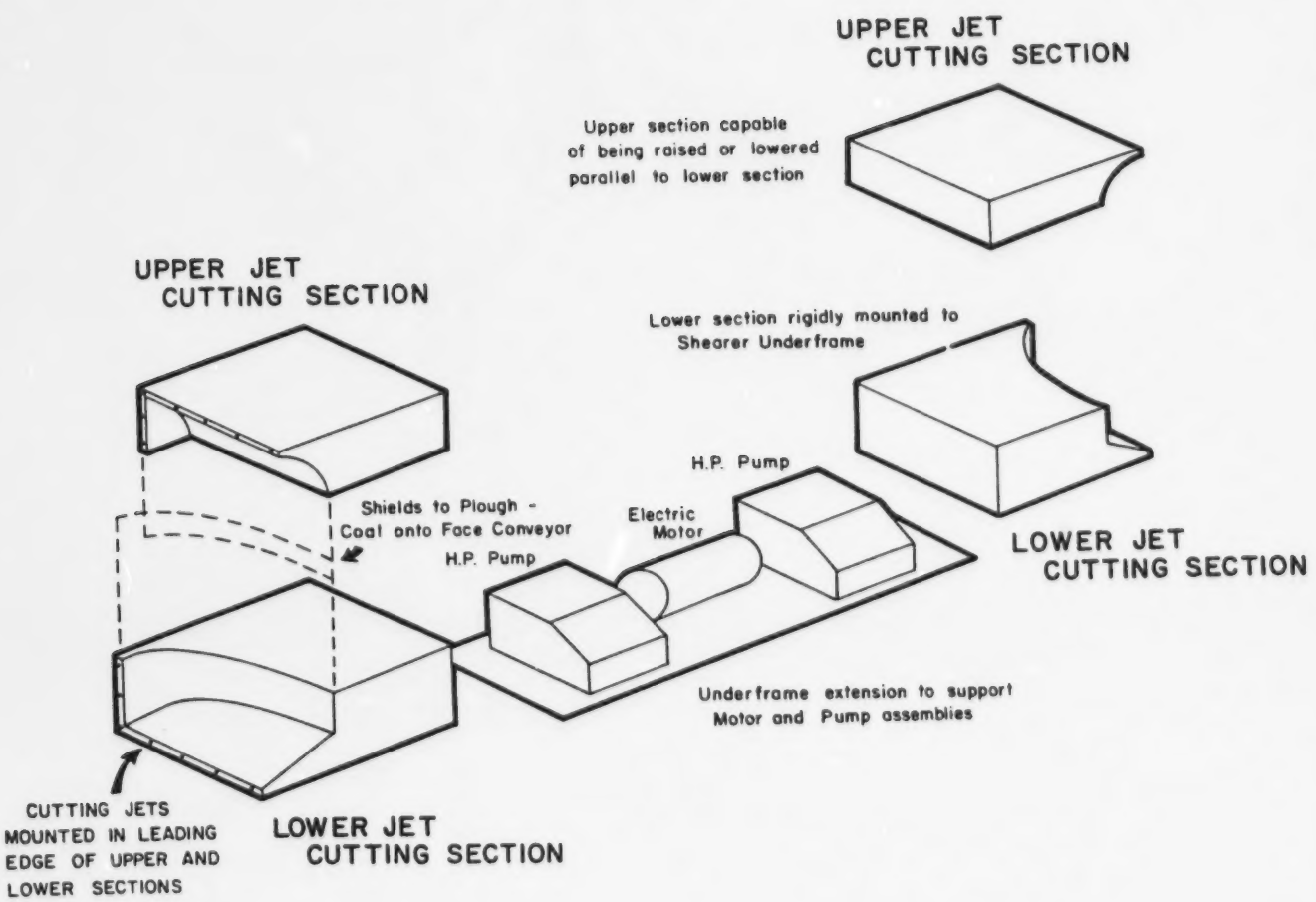


FIGURE 6-10
ALTERNATIVE LONGWALL FACECUTTING SYSTEMS
FOR THE SYDNEY COALFIELD

HYBRID SHEARER CONCEPT



AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD DSS # 03SQ.23440-3-9187

SECTION 7 - SYSTEM DEVELOPMENT

Table of Contents

		Page
7.1	General	7-1
7.2	Slicer	7-1
7.3	Water Assisted Plough	7-2
7.4	Hybrid Shearer	7-2
7.5	Conclusions	7-3

SECTION 7 - SYSTEM DEVELOPMENT

7.1 GENERAL

The study has identified three candidate systems worthy of further development - the hybrid shearer, the slicer and the water jet plough. Al three can be considered as alternatives to the conventional DERDS with significant frictional ignition hazard reduction potential. Since none of these systems are currently at a fully operational status it would be prudent to encourage the further development of all three to provide the best opportunity for the successful development of at least one to an operational stage. We consider that the development of each of the three machines, because of their various stages of development should be treated differently.

7.2 SLICER

The slicer is an established machine, but now obsolete. CANMET/CBDC should enter into discussions with the manufacturers of the slicer - Huwood Limited - to determine whether they are willing to develop an updated slicer to meet CBDC's requirements. In return for Huwood's development work, CBDC should offer to provide the site for field trials of an updated machine, provided that the machine's specifications meet CBDC requirements.

In situations where the slicer is well matched to the mining conditions, excellent performances have been obtained and an updated slicer has considerable potential for application in the Sydney Coalfield conditions. CANMET/CBDC should, therefore, collaborate with Huwood to encourage the development of a modern slicing machine.

7.3 WATER ASSISTED PLOUGH

The GHH plough is currently awaiting further field trials in Germany. CANMET/CBDC should follow the progress of the trials in Loberg Colliery and should maintain a close contact with both the manufacturers and the engineering and operating staff at the mine in order to obtain their views on the capabilities of the machine. A visit should be made to view the machine in operation by CANMET/CBDC personnel. On the conclusion of the scheduled field trials CANMET should commission a detailed evaluation of the GHH plough and its potential for application in CBDC conditions. In the event of positive findings, CBDC should negotiate with the manufacturers the conditions for an in-mine trials of the GHH plough. The water jet assisted plough offers considerable promise for frictional ignition hazard reduction.

7.4 HYBRID SHEARER

The concept for a machine of this configuration was developed by the study team, consequently it is less well developed than the other two candidate systems, but is the least radical in concept, being basically a DERDS with the addition of water jet roof and floor cutting elements.

It is noted that Gebr. Eickhoff of Germany through their subsidiary ETE Corp. are expending considerable time and effort on the development of a high pressure jet under USBM contract # JO.145029, July 31, 1984. The program is directed toward the development of a high pressure jet cutting system which can be installed on shearer machines to replace the mechanical cutting action of picks deployed around the shearer drum, with water jets. Although consideration of this system was specifically excluded from the Terms of Reference for this study, clearly the development of suitable high pressure pumps and water supply systems for this purpose could be readily adopted for use with the hybrid shearer concept.

Because of the high degree of compatability with the existing mining systems and the other advantages discussed in Section 5, we consider that CANMET/CBDC should direct their main efforts toward the further development of this system.

CANMET/CBDC should commission a detailed feasibility study of the hybrid shearer including definition of any further detailed testing required for machine development - for example, jet cutting tests in CBDC mines to finalize cutting, design, water pressure and quantity, machine design, trial site identification and cost/performance evaluation.

If the findings of the feasibility study are positive then CANMET/CBDC should negotiate a cost sharing arrangement with an established mining machinery company for the construction of a prototype hybrid shearer. CBDC should offer to provide a site for a field trial.

The evaluation and development of the hybrid shearer concept could lead to the development of a mining system well suited to the environment in the Sydney Coalfield, but also with potential for application in other coalfields with similar problems. CANMET/CBDC should structure any agreement with a manufacturer in such a way as to retain an interest in the wider applications of a hybrid shearer.

7.5 CONCLUSIONS

All three of the candidate systems discussed have potential for application in CBDC conditions. CANMET/CBDC should ensure that further development of all three machines is either promoted, encouraged or reviewed so that at the earliest possible time positive steps can be taken to introduce one or more of these machines on a trial basis into the CBDC operations. However, it is believed that the

most significant benefit to CBDC would accrue from the development of the hybrid shearer concept.

Successful development of this system would require the minimum change to mining equipment currently employed and is likely to be effected at least cost. In the consultants' view this concept should be accorded high development priority.

AR-80

ALTERNATIVE LONGWALL FACECUTTING SYSTEMS FOR THE SYDNEY COALFIELD DSS # 03SQ.23440-3-9187

SECTION 8 - CONCLUSIONS AND RECOMMENDATIONS

Table of Contents

		Page
8.1	Conclusions	8-1
8.2	Recommendations	8-2

SECTION 8 - CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

- Geologic conditions in the sydney Coalfield are such that the possibility of frictional ignition may be present on any of the longwall panels in the existing or proposed mines.

- The most hazardous zones from a frictional ignition viewpoint are the roof and the floor of the seams.

- The double ended ranging drum shearers currently being employed produce high output per machine shift and high face productivity. Any alternative facecutting system must be able to produce in excess of 1500 t/shift at 40 t/manshift productivity.

- Retreat mining will become the most widely adopted mining layout in the Sydney Coalfield and itself offers some benefits from a frictional ignition hazard reduction perspective.

- Three candidate alternative facecutting systems have been identified:

  - slicer
  - water jet plough
  - hybrid shearer.

- None of these machines are yet in commercial production and require further development efforts before they could be put into service as an alternative to the shearer.

8.2 RECOMMENDATIONS

- Discussions should be held with the manufacturers of the slicer to determine whether an upgraded machine can be produced that would be technically and commercially attractive to CBDC.

- The current series of field trials of the GHH Jetminer water plough in Germany should be closely monitored by CANMET/CBDC.

- CANMET should initiate further detailed studies of the hybrid shearer concept to evaluate its feasibility and to define the schedule and organization of further developmental activity. This machine has considerable potential for producing high productivities and production levels while retaining the majority of the existing longwall equipment, with a considerably reduced frictional ignition hazard potential.

APPENDIX A

Selected Bibliography

SELECTED BIBLIOGRAPHY

Anon

1982: **Coal Winning Machine Using High Pressure Water Jets;** Coal Int., V.1/3, (Oct.), p 37-38.

1982: **Combating Frictional Ignitions;** Min. Environ. Bull., No.5 (July), p 18-19.

1979: **The Deveo No.26 Explosion;** Can. Min. J., V.100, No.4 (April), p 100-105.

1916: **Coal Miners' Pocket Book, 11th ed.;** McGraw Hill; Machine Mining, p 644-648.

Anderson, Forrest S. and Thorpe, Robert H.

1967: **A Century of Coal-Face Mechanization;** The Mining Engineer, Vol.126, No.83, p 775.

Bakke, P.; Leach, S.J. and Slack, A.

1967: **On the General Body Concentration and Other Ventilation Data as a Measure of the Average Risk of Ignition;** The Mining Engineer, Vol.126, No.83, p 725.

Barker, C.R. and Summers, D.A.

1977: **Consideration in the Development of a Water Jet Cutting Head;** Proc. 18th Symp. on Rock Mech., Keystone, CO, p 2B4.1-2B4.9.

1978: **Surface Trials of the Hydrominer;** 4th Int. Symp. on Jet Cutting Technology, Canterbury, England, April 12-14.

1978: **Testing of the Prototype Hydrominer in a Surface Coal Seam;** Min. Eng., Apr. pp. 379.

1981: **The Development of Longwall Water Jet Mining Machine;** Univ. of Missouri - Rolla; Final Rpt. Contract DOE AC01 75ET 12542, 200 p.

Barker, C.R. et al.

1978: **Testing of the Prototype Hydrominer in a Surface Coal Seam;** Min. Eng. (NT), V.30, No.4 (April), p 379-383.

Baumann, L. and Koppers, M.

1982: **High Pressure Waterjet Assisted Road Profiling;** Coll. Guard. V.230, No.9 (Sept), p 477-479.

Baumann, L, and Markus, M.

1982: **High Pressure Waterjet Assisted Road Profiling;** Col. Guard., V.230/9, Sept., p 477-479

Bingham, T.R.

1981: **Incendive Sparking Associated with Shearer Machines;** Proc. Ignitions, Explosions and Fires in Coal Mines Symp., Aust.I.M.M., Illawarra Branch, (May), pp 3-1 - 3-10.

Bituminous Coal Research

1982: **Frictional Ignition Suppression by the Use of Cutter-Drum Mounted Sprays;** U.S.B.M. Rep. of Inv. 7930.

Blickensderfer, R. et al

1972: **Testing of Coal Cutter Materials for Incendivity and Radiance of Sparks;** USBM Rep. of Inv. 7713.

1974: **Incendivity of Some Coal-Cutter Materials by Impact-Abrasion in Air-Methane;** US Bu.Mines R.I. 7930, 20 p.

Bobrov, A.I. and Petchenko, N.G.

1982: **Causes of Methane and Air Mixture Ignitions in Mines;** HSE (US) Transl. No.10206, 4 p; Orig. Pub. in Russian, UGOL, March 1982, p 48-49.

Brooker, G.M.

1979: **Theoretical and Practical Aspects of Cutting and Loading by Shearer-Drums;** Colliery Guardian, Coal International.

Courtney, W.G.

1981: **Preventing Frictional Ignitions;** Coal Min. & Proc. (Jan), pp 48-58.

Courtney, W. et al.

1981: **Frictional Ignition Problems in US Coal Mines;** 19th Int. Res. Inst. Safety in Mines, Katowice, Oct. 5 p.

Cutler, D.P.

1978: **Further Studies of the Ignition of Gases by Transiently Heated Surfaces;** Combust. Flame, V.33, P 85-91.

Dirner, V.

1982: **Reducing the Methane Ignition Hazard During the Drivage of Long Headings by Means of Cutter-Loader and the Possibilities for Effective Prevention of Coal Dust Formation;** NCB/MRDE Transl. No.1932, 10 p; Orig. pub. Mech. i Automat. Cornictwa, V.10, No.163, p 29-33.

Ekber, B.J. and Kuzmich, L.A.

1980: **Coal Cutting Technology with Water Jets in the USSR;** 5th Int. Symp. Jet Cut. Tech., Hanover, F.R.G., Paper E5, p 297-302.

Ekber, B. and Markus, M.

1982: **The Hydraulic Mining of Coal in Societ Coal Mines;** Proc. 6th Int. Symp. Jet Cut. Tech., Guildford, UK, Paper G5, p 335-346.

Evans, I.

1983: **Picks and Frictional Ignitions;** The Mining Engineer, Vol.142, No.256, p 417.

Evans, L.

1983: **Picks and Frictional Ignitions;** Min. Eng. (London), V.142, No.256 (Jan), p 417-418.

Franke, H.

1977: **Determination of Minimum Ignition Energies of Coal Dust - Methane - Air Mixtures (Hybrid Mixtures);** 17th Int. Conf. Safety in Mines Res., Varna, Bulgaria, 16 p.

Golledge, P.

1981: **Sources and Facility of Ignition in Coal Mines;** Proc. Ignitions, Explosions and Fires in Coal Mines Symposium. Aust. I.M.M. Illawarra Branch, (May), pp 2-1 - 2-12.

Groh, H. and Eisfeld, D.

1982: **On the Work of the Mining Test Colliery;** Kompass, V.92, No.7 (July), p 261-265, in German.

Hamilton, R.J., French, A.G. and Browning, E.J.

The Extraction Drum: Benefits in Dust and Firedamp Control; NCB, MRDE, UK.

Hart D.E.B. and Smith P.A.

1959: **The Huwood Electric Slicer and its Application;** Huwood Pub. 26/27.

Heincker, W.R., et al

1976: **A Hydraulic Longwall Mining Design-Concept for the Future?:** World Coal, Vol.2/2, Feb. pp 23-26.

1976: **Design of a Hydraulic Longwall Coal Mining Machine;** Preprint No. 76-WA/DE-2, Am. Soc. of Mech. Eng. Winter Annual Meeting, New York, December.

Henkel, E.H.

1980: **Aims for a High Pressure Water Jet Assisted Coal Winning System;** 5th Inc. Symp. Jet Cut. Tech., Hanover, F.R.G. Paper E6, p 303-312.

H.M. Inspectorate of Mines and Quarries

1982: **Explosion at Cardowan Colliery;** Colliery Guardian (Nov.), pp 557-563.

Jones, J.T.E.

The Installation and Trials with the Hywood Slicer at Dinnington Colliery, South Yorkshire; NCB North Eastern Div. No.1 Area.

Kawecki, Z.

1979: **The Development of Mining Machines and Equipment as a Factor Improving the Technology of the Polish Coal Mining;** Int. Conf. Min. Machines, Brisbane, Australia, Part 1, p 232-237.

Kawenski, E.M. et al

1979: **Frictional Ignition of Methane by Continuous Mining Machines in Underground Coal Mines;** Mine Safety & Health Admin. (US), I.R. 1110, 11 p.

Kelley, J.E. and Forkner, B.L.

1976: **Ignitions in Mixtures of Coal Dust, Air and Methane from Abrasive Impacts of Hard Minerals with Pneumatic Pipeline Steel;** US Bu. Mines RI 8201, 19 p.

Kocherga, M.G. et al

1981: **Avoiding Methane Ignition by Friction Sparks During the Operation of Mining Equipment;** Translation No. MRDE 1450 (UK), 9 p. From Ugol'ukraini (Jan), 1981, pp 25-26.

Kramer, Th.

1982: **Jet-miner Surface Trials Run at Bergbau-Forschung, Germany;** Proc. 6th Int. Symp. on Jet Cutting Tech., April, Sponsored by BHRA Fluid Engineering.

Lampl, F.

1982: **What Next in Longwall?;** Dowty Mining Symp. May.

Larson, D.A. et al

1983: **Preliminary Evaluation of Bit Impact Ignitions of Methane Using a Drum-Type Cutting Head;** USBM Re. of Inv. 8755.

Laurendeau, N.M.

1982: **Thermal Ignition of Methane-Air Mixtures by Hot Surfaces: A Critical Examination;** Combustion and Flame 46, pp 29-49.

Leach, S.J. and Walker, G.L.

The Application of High Speed Liquid Jets to Cutting; SMRE Min. of Power, Sheffield, UK.

Lewis, W.T. et al

1983(?): **Circumstances Generating Incendive Sources in Rock Cutting;** MRDE (UK), NCB, Session D, 10 p.

National Coal Board

1974: **Geological Assessment of Faces and Headings to Determine the Incendive Temperature Potential of Rocks;** Mining Dept. Instruction PI/1974/4, NCB (UK), (Oct. 15), 3 p.

Potts, E.L.J.; Roxborough, F.F. and Whittaker, B.N.

1967: **Experiments with the Automatic Variable Geometry Coal Plough;** The Mining Engineer, Vol.126, No.80, p 539.

Powell, F. et al

1975: **The Ignition of Methane-Air by Machine Picks Cutting Into Rock;** 16th Int. Conf. Coal Mine Safety Research, Washington DC, USA, Sept. 22-26, VII, pp 7.1-7.10.

Powell, F. and Billinge, K.

1975: **The Frictional Ignition Hazard Associated with Colliery Rocks;** Min. Eng. (July), pp 527-533.

1979: **The Use of Water in the Prevention of Ignitions Caused by Machine Picks;** I.Min.E., London.

Roepke, W.W.

1983: **Bit Ignition Potential with Worn Carbide Tips;** USBM Tech. Prog. Rep. 121.

Roepke, W.W. and Hanson, B.D.

1982(?): **Testing Modified Coal-Cutting Bit Designs for Reduced Energy, Dust and Incendivity;** US Bu. Mines, R.I. 8801, 31 p.

Schwarting, K.H. et al

1981: **Development and Underground Testing of High Pressure Water Jet Coal Cutting Proceas;** Glueckauf.

Singhal, R.K. and Ward, D.W.

1964: **The Method of Ploughing Coal;** Journ. of Mines, Met. & Fuels, April.

Stafford, S.

1981: **Coal Mine Ignitions of Methane by Friction Show Five-Year Rise;** Mine Safety & Health, p. 10-15, May-June.

Summers, D.A.

1978: **The Use of High Pressure Water Jets in the Mining Industry;** Colliery Guardian, October.

1982: **The Commercial Development of Water Jet Coal Mining Machines;** Conf. on Water Jet Technology, West Virginia University, April.

Summers, D.,A., et al

1974: **Experimentation Leading to the Design of a Longwall Water Jet Mining Machine;** Final Rep. on USBM Contract H0232064, November.

Summers, W.A.

1982: **The Oldest Miner of Them All;** Inst. Min. Eng, Newcastle-upon-Tyne, UK.

Summers, W.A. and Summers, D.A.

1978: **The Application of High Pressure Water Jets to Longwall Mining;** I.Min.E. Newcastle-upon-Tyne, UK

Tebbs, J.G.

1956: **The Hywood Slicer-Loader;** Ext's. from a paper presented before the North of England Inst. of Min. and Mech.Eng.

Trumper, T.

1982: **The State of the Ploughing Technique;** Coal Int. Vol.1/1, April, pp 17-20, 22-23.

Watson, R.W.

1981a: **Coal Mine Ignitions of Methane by Friction Show Five-Year Rise;** Mine Safety & Health (May-June), pp 10-15.

1981b: **Prevention and Suppression of Gas Explosions in Mines;** Proc. Ignitions, Explosions and Fires in coal Mines Symp., Aust. I.M.M. Illawarra Branch, (May), pp 6-1 - 6-13.

Wehrle, J.C.

1970: **The Slicer Machine at Maltby Colliery;** The Min.Eng., UK.

Whittaker, B.N.

1967: **Coal Plough - Theory and Design;** The Mining Engineer, Vol.126, No.76, p 323.

POOR

QUALITY

ORIGINAL